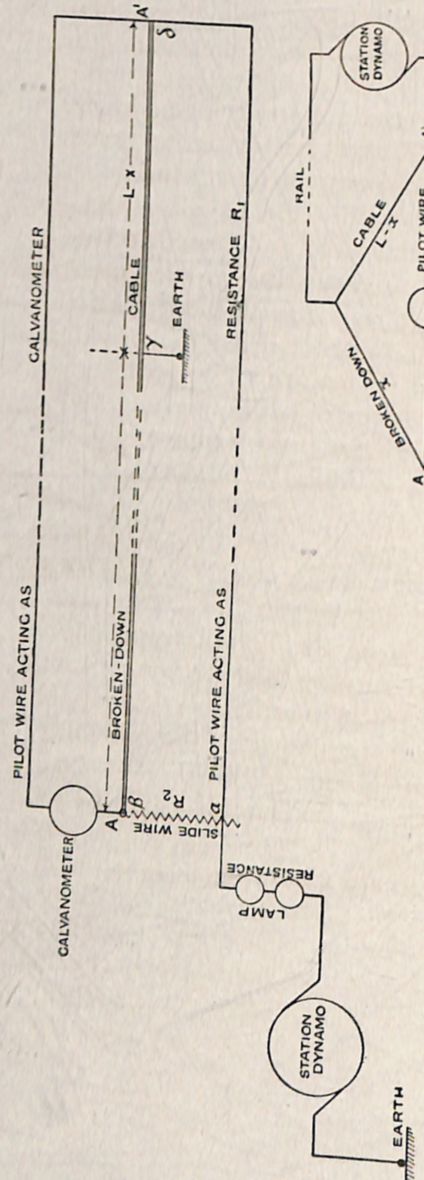
D_2 being the smaller deflection and L the length of the cable. The readings D_1 and D_2 must be averaged from readings got with the current flow reversed. Murray's loop is so well known that it scarcely requires any reference, beyond a caution that the contacts of the slide wire with the loop terminals must introduce no resistance, and that one must not be deluded into balancing to false zero. Any deflection on the galvanometer, noticed when it is joined up but the testing voltage not impressed, is merely due to some battery action at the fault. Another excellent null method is sketched in fig. 91. If, besides the broken-down cable, there are available two sound telephone or test cores, the latter should be joined up to the distant end in such a way as not to introduce any resistance at the joint δ. One of these is a voltmeter lead only, the other is a resistance (R_1), determined by measuring the resistance of the looped pair and dividing the result by two. To the near end of the cable (β) a uniform slide-wire is jointed in such a way as to introduce no resistance, and brought in contact with R_1 in such a way that no resistance is introduced. By sliding along the wire a position is found at which no deflection is got on the voltmeter V when a wire tapped through a bank of lamps on to the trolley wire or a live cable is applied to a. Then plainly the distance away of the fault is



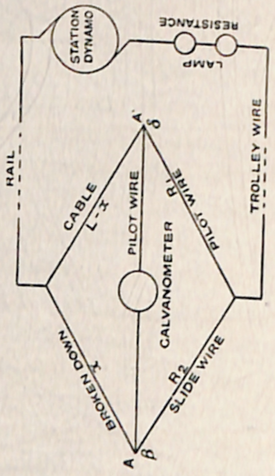


Fig. 91

$$L \cdot \frac{R_2}{R_1 + R_2}.$$

In the case of a cable with its core broken in two, but well insulated from earth, it is possible to apply a capacity test, but it is not often that the chance is got. Generally the cable is well earthed. For a cable sheathed in vulcanized bitumen, without lead covering or armour, an induction test is sometimes successful. A frame in the shape of an equilateral triangle, with sides 1 yard long wound with 250 turns of No. 30 wire, and fitted with a very sensitive telephone receiver is suitable. The

fault should be well broken down to earth, so as to admit of a current being sent through it amply large enough to entirely swamp the cable's capacity-current, and the current should be sent with a distinct set of slow rhythmical pulsations; such a signal as " - - - —" being readily made out above the squealing sounds emitted by loaded cables. For lead-covered cables, especially laid solid, the test is a failure. When successful, the signals cease abruptly or become very much fainter when the fault is passed. Care must be taken to have the overhead work dead if one is going to tap the current through the fault from a section-box, else the surging of the current in the trolley wires will be heard in the telephone and prove utterly confusing. A better arrangement is shown in fig. 92. If a current of a few amperes be sent through the fault to earth, and a millivoltmeter with steel (not copper) contacts is applied along the *rail*, deflections will be obtained which on the faults being passed will abruptly

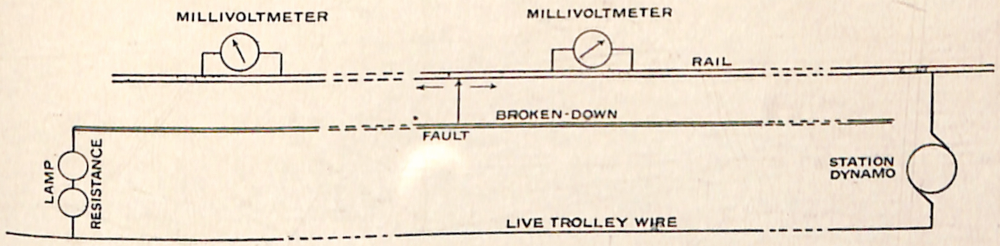


Fig. 92

change their direction and diminish greatly. This test can only be applied when there is nothing but the testing current flowing in the rails.

For breaking down a cable, three transformers, coupled up with their low-tension windings in parallel and their high tension in series, will give thrice the voltage of one of them, which is usually ample. In the low-tension circuit a water resistance whose plates can be readily swung apart is a great advantage, as it enables the arc at the breakdown to be changed from its almost explosive character to a quiet discharge which soon welds up a satisfactory contact with earth.

Of course there is danger in such work, and all concerned should be familiarized with the procedure necessary in a case of electric shock. Notwithstanding its cost, the Pulmotor is so remarkably successful at resuscitation that one should be available in every electricity-supply concern.

CHAPTER VI

OVERHEAD CONSTRUCTION

General Considerations.—The overhead system may be divided into the following classifications:—

1. Span-wire construction (fig. 93), adaptable to practically all possible conditions of working.

2. Bracket suspension, subdivided into (1) centre-pole and double-bracket (fig. 94), and (2) side-bracket construction (fig. 95). The former is only applicable to double track and wide streets. The latter may be arranged with brackets on one side of the street, suitable for comparatively narrow streets, or on both sides, applicable to fairly wide streets.

Another general classification may be made of lines constructed for the centre-running trolley and for the side-running trolley. In the former case the trolley head is rigid (fig. 96), and the trolley wire follows as nearly as possible the centre of the track, the deviations from the centre line allowable not being more than a couple of feet.

For the side-running trolley, the trolley head is pivoted so that it can turn completely round (figs. 95 and 97), and in this case the trolley wire need be only approximately parallel to the track and as far from the centre as the length of the trolley arm will permit.

Choice of System.—In laying out an overhead system the first point to be determined is the desirability of using mechanically-moved or fixed frogs, this point determining which type of trolley can be used.

If the fixed frog is decided upon, it necessitates the use of a centre-running trolley with a rigid head. If the mechanically-moved frog is considered most desirable, the centre-bearing trolley can be used, but it is preferable to employ the side-bearing trolley with its greater allowable variations in the relative positions of track and trolley wire. This enables the number of pull-off wires and insulators to be reduced to a minimum.

Fig. 96.—Harp for Rigid Trolley Head

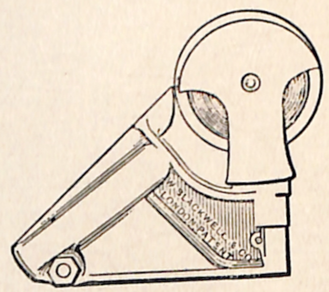


Fig. 97

The mechanical frog is much more reliable than the fixed frog, and, if properly designed and set, presents no greater probability of the trolley leaving the wire than straight track. It, however, necessitates a separate attendant to set it for the desired direction, otherwise the conductor or driver must leave his post in order to set it. The former entails annual expenditure the amount of which depends upon the number of branch lines to be operated, and the latter delays the car while the frog is being set.

If the street is of sufficient width to allow the use of the centre-pole form of construction this delay will be negligible, but if it is necessary to place the poles on the footpath the delay would be considerable, and in a street having heavy vehicular traffic it might be serious. This would also mean expense to the tramway and inconvenience to passengers. As junctions usually occur in more or less busy places, working the frogs would seriously interfere with a conductor's duties, and it is always extremely bad practice to have a driver leave his post. Therefore a mechanical frog will in most instances necessitate an attendant, and as tramways usually work from sixteen to eighteen hours a day, it would require the services of two

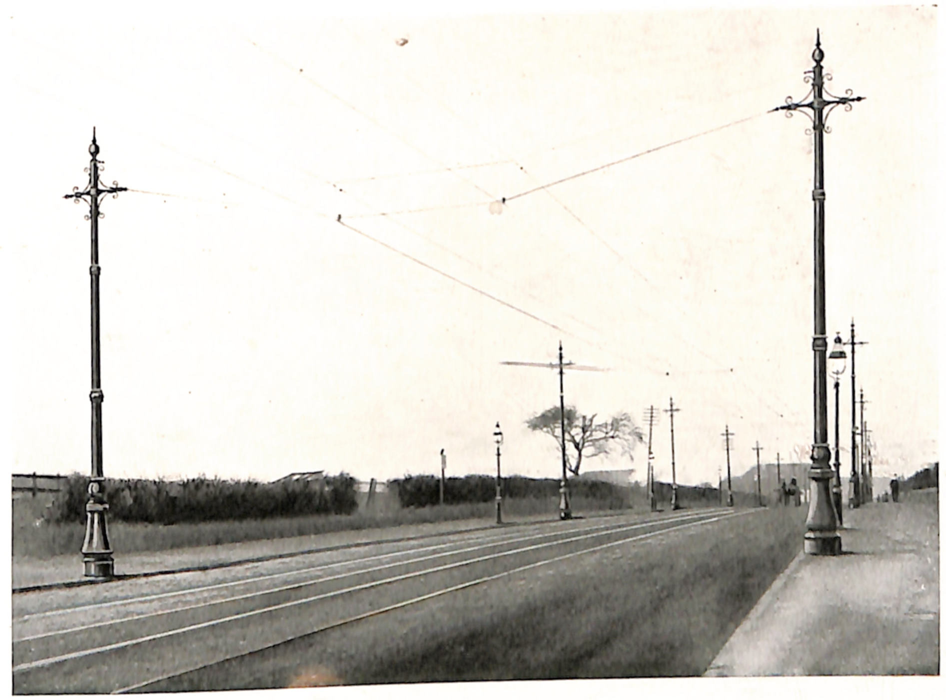


Fig. 93.—Span-wire Construction

Fig. 94.—Centre-pole Construction, Rigid Arm

Fig. 95.—Side-bracket Construction, Rigid Arm

men at each junction. As against this, the working of the mechanical frog is so reliable that the conductor can tie up the trolley cord and give his entire attention to the collection of fares. Owing to the short distances that many passengers are now carried this is an important advantage.

The fixed frog at simple junctions can be made to work with very nearly the certainty of the movable frog, but not to the degree of tying up the trolley cord before-mentioned, and it is always necessary for the conductor to watch the trolley with some care at junctions.

The next point to be determined is whether the centre-bearing or side-bearing trolley is to be used.

If the system of tramways consists of fairly straight routes, and the centre-pole or span-wire construction can be used throughout, or side-bracket construction on single track with streets not over 30 feet between the kerbs, and if æsthetic considerations are not of the first moment, the centre-bearing trolley with the rigid head will be quite satisfactory; but in cases where span-wires are objected to, the side-running trolley, having a greater degree of flexibility, will be found the more serviceable. It has the very marked advantage of being able to work with the trolley wire 12 feet or even 15 feet from the centre of the track, and to get around curves with very few pull-off wires, but it must be remembered that it is not good policy to continually strain these valuable features to their limit. It may be taken as a principle that the closer the trolley wire is to the centre of the track the better it will work, and it is sound practice that the trolley wire should not be farther than 6 feet from the centre of the track unless there are special local reasons for exceeding this distance. This distance can be worked very nicely with a 12- or 13-foot trolley arm, which is a standard length; a greater length of arm very materially increases the stress on the trolley standard and car roof at points where it is difficult to increase the strength.

It is also not advisable to reduce the pull-offs at the curves to their absolute minimum, as, although the swivel-head trolley will take a very sharp angle, the sudden change of direction tends to make the wheel leave the wire if anything about the trolley wheel or stand is not in perfect condition. There is also some danger, with very sharp angles, of putting more strain on a single insulator than it can be constructed to bear. This will lead to failure of the insulator, which, on account of the heavy strain, would be very troublesome to replace.

Construction at Different Points.—The type of construction to be used at different points of the system will next require consideration.

Of the several types—span-wire, centre-pole, and side-bracket—the span-wire is undoubtedly the best from a mechanical standpoint and as regards smoothness of working. This system is applicable to every width of street and to practically all conditions of service. The sole objection that can be raised against it is on æsthetic grounds. In some cases span-wires are erected without the use of poles, by attaching the span-wires to fixtures (figs. 98 and 99) bolted to the fronts of buildings along the route. This is a very satisfactory method of construction, as it embodies all the good features of the span-wire system and is the least conspicuous form of overhead construction that has been devised.

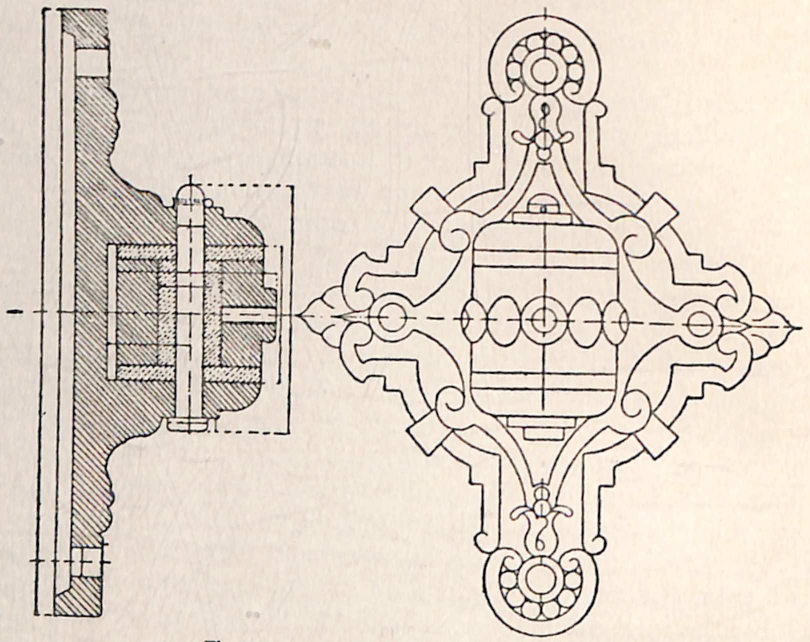


Fig. 98.—Section and Elevation of Rosette, large

The centre-pole and double-bracket form of construction lends itself to ornamentation, particularly in conjunction with electric lighting, better than any other method. With its short brackets, bringing the trolley

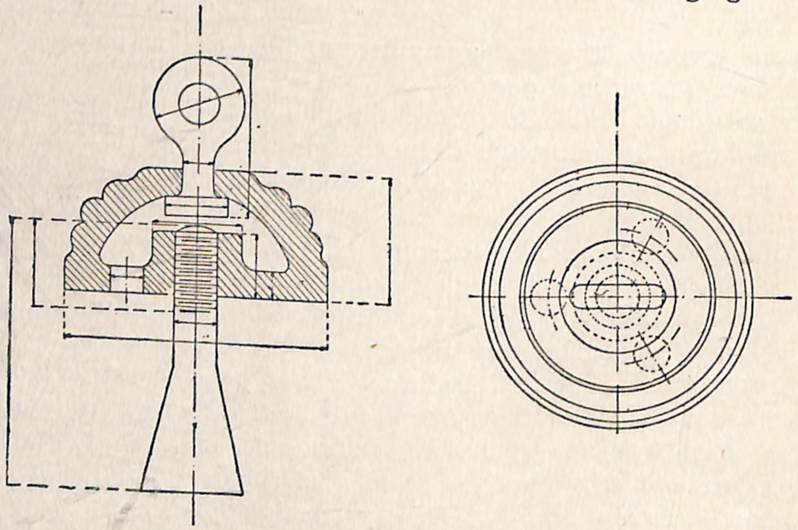


Fig. 99.—Section and Elevation of Rosette, small

wire close to the centre of the track, it is, when flexible suspension is used, mechanically second only to the span-wire. The poles, however, constitute a danger to traffic.

The side-bracket construction is in most instances the least desirable from a mechanical standpoint, but has been very largely used. The brackets vary in length from 3 to 25 feet. Brackets of such great length as the latter should be avoided when possible, as they are difficult to construct of sufficient strength, are expensive, and have nothing in their appearance to recommend them. With brackets placed at the usual height, 22 feet from the kerb, a length of 8 to 10 feet is the proportion most pleasing to the eye, and anything beyond about 16 feet begins to look top-heavy. A 16-foot bracket will give 14 feet of effective length from the kerb to the trolley wire, and by adding to this the 6-foot reach of the trolley arm, previously referred to, the total reach is 20 feet, which would enable a single track to be worked from the centre of a 40-foot street. This is about as wide as will often be met with in English practice.

Poles.—Numerous types of poles have been tried, but the tubular steel pole has now become standard practice (fig. 100).

There are three types of tubular steel poles; the first and most largely used consists of three lengths of pipe of various diameters, telescoped into each other, the sections of pipe being either solid-drawn or lap-welded.

Table A shows some of the usual sizes of poles and the thickness and weight of metal.

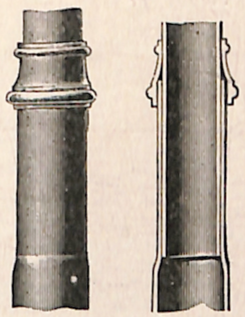


Fig. 100.—Section and Elevation of Pole Joint

Taper Poles.—A second type of pole is met with, having a taper either for the whole or part of its length. These are usually drawn parallel for 15 or 17 feet of their length, and from thence tapering to the end. They are sometimes made in one piece and sometimes in two, the lower or parallel section being shrunk over the upper or taper section. Although these poles have been used on a number of tramways, there appears to be no special advantage in them other than their appearance, which is in some cases preferred to that of the three-jointed pole. The taper pole does not lend itself to ornamentation as well as the parallel-sided pole.

Solid-drawn Poles.—The third variety of pole is solid-drawn in one piece and of three different diameters, the sides being parallel. The appearance of these poles is practically the same as the jointed poles. Poles drawn by this method should have advantages over both of the other types, but in practice they are not found absolutely reliable in strength.

Poles are usually designated by the number of pounds stress they will bear with a given deflection, usually 6 inches, it being assumed that the pole is held securely for the first 6 feet of its length, and the stress is either applied at the top, or, what is more convenient, at the point where a stress will come in practice, usually about 22 feet from the ground-line The temporary deflection of 6 inches has come into general use, as a pole may be curved to this extent after erection and yet appear straight to any but a trained eye.

Poles are generally specified to be perfectly straight and to show no permanent deflection at the designated strength. An additional test is sometimes specified, that the poles shall not show more than $\frac{1}{2}$ inch permanent deflection after being subjected to a stress about 50 per cent greater than the designated strength. The diameters of the various sections should not vary more than $\frac{1}{16}$ inch from the standard dimensions, and the

TABLE A

THREE-SECTION LAP-WELDED STEEL POLES

Tensile strength about 24 tons per square inch.

Top Section, 7 feet 6 inches.		Middle Section, 9 feet 6 inches.		Bottom Section, 17 feet.		Total, 31 feet.	Strain in lbs. to produce	
Inside Diameter, inches.	Thickness, inches.	Inside Diameter, inches.	Thickness, inches.	Inside Diameter, inches.	Thickness, inches.	Weight of Pole.	6 inches Temporary Deflection.	$\frac{1}{2}$ inch Permanent Set.
4	.23	5	.29	6	.42	720	350	700
5	.26	6	.31	7	.40	836	500	1000
5	.30	6	.38	7	.47	990	700	1200
6	.30	7	.40	8	.60	1321	1000	1700
7	.30	8	.40	$9\frac{3}{4}$	.65	1593	2000	2600
Tensile strength 28 tons.								
9 feet.		8 feet.		17 feet.				
Outside.		Outside.		Outside.				
$5\frac{1}{2}$	.259	$6\frac{5}{8}$	.30	$7\frac{3}{4}$	.40	830	900	...
$6\frac{5}{8}$	.30	$7\frac{3}{4}$	.40	9	.50	1210	1200	...
THREE-SECTION SOLID-DRAWN STEEL POLES. Tensile strength 35 tons per square inch.								
7 feet 6 inches.		9 feet 6 inches.		17 feet.				
Outside.		Outside.		Outside.				
$4\frac{1}{2}$	.30	$5\frac{9}{16}$	.30	$6\frac{5}{8}$	.375	720	500	1000
$5\frac{9}{16}$	.30	$6\frac{5}{8}$	.30	$7\frac{5}{8}$	.3125	800	700	1200
$6\frac{5}{8}$	.30	$7\frac{5}{8}$	.30	$8\frac{5}{8}$	.3125	890	1000	1700
$7\frac{5}{8}$	.3125	$8\frac{5}{8}$	.3125	10	.375	1140	2000	2600
POLES IN ONE LENGTH STEPPED. Tensile strength 35 tons per square inch.								
6 feet.		6 feet.		19 feet.				
Outside.		Outside.		Outside.				
4	.3125	6	.3125	$7\frac{3}{4}$	.3125	680	700	1200
5	.3125	7	.3125	$8\frac{3}{4}$	.3125	796	1000	1700
7	.3125	$8\frac{1}{2}$	.3125	$10\frac{1}{4}$	.3125	922	2000	2600
Lap-welded taper poles in one piece; the bottom half their length parallel, the top half tapering.								
Outside 7 inches tapering to Outside 5 inches; thickness, $\frac{3}{8}$ inch						780	700	...
8 ,, ,, 6 ,, ,, $\frac{7}{16}$,,						1025	1000	...
9 ,, ,, 7 ,, ,, $\frac{1}{2}$,,						1300	1200	...
7 ,, ,, 4 ,, ,, $\frac{3}{8}$,,						740	700	...
8 ,, ,, 5 ,, ,, $\frac{7}{16}$,,						1050	1000	...

tubes should be as nearly cylindrical as possible. The difference between the maximum and minimum diameters should not exceed $\frac{1}{8}$ inch. The necessity for these limits of variation is that the cast-iron pole trimmings shall fit easily. Where poles are made in more than one piece a drop test is also requisite. The usual test is to drop the pole, butt foremost, from a height of 6 feet on to some solid substance, such as a block of iron or stone.

Care should be taken to protect the poles from rust inside and beneath the ground-line. One method of accomplishing this is to dip them about 7 feet into a suitable rust-preventing compound. Another is to dip the entire pole in a bath of oxide paint, thus coating it inside and out. It might even be advisable to adopt both methods. It is a distinct advantage to coat the first 2 or 3 feet above the ground-level with sound cement about 1 inch thick.

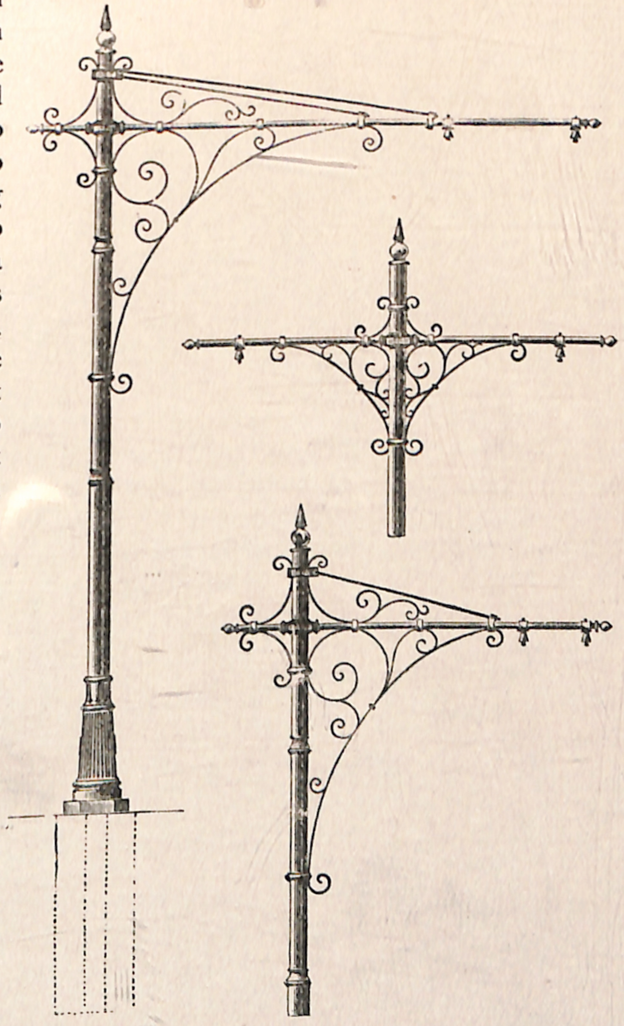


Fig. 101.—Various Forms of Bracket Design

Pole Trimmings and Brackets.—The design and dimensions of these will be largely governed by individual taste and the money available for purposes of ornamentation. They usually consist of a finial slipped into the top of the pole, two pole rings or collars slipped over the joints or shoulders, in a parallel-sided pole, and a base of such height and design as may be desired. In some cases small, low, plain bases are used in the outlying portions of the system, and in others the high bases are used throughout. In selecting designs for these the smaller and simpler types should be chosen.

Brackets are of two general varieties—one consisting of a piece of tubing of suitable diameter, usually $2\frac{1}{2}$ to 3 inches, and of a required length. This is supported to some extent by the scroll-work underneath, but chiefly by a tension-rod running to the top of the pole (fig. 101).

The second type (fig. 102) is what is usually known as the bow-string bracket. This is not, mechanically, a good design, but has met with a very considerable amount of favour, particularly for centre-pole work, as the absence of straight lines is supposed to give a pleasing effect to the pole. It is made up entirely of wrought iron of suitable sections, which must, however, be much heavier than in the first type of bracket. In both cases heavy cast-iron collars made in two pieces are held together by two or four bolts (fig. 103). The inside of these collars should fit the circumference of the pole as closely as possible, and to them are attached the bracket arms proper or the scroll-work. Similar collars, but smaller, are also used to secure the scroll-work to the bracket arm in the case of a pipe bracket. All these collars, upon which the strength of the bracket depends, are made of malleable cast iron. The scroll-work is made to suit the taste of the designer; the various portions are held together in some cases by welding and in others by having small iron collars cast about them. If expense is to be avoided, the design should be such as may be made with the fewest number of welds. Circles should also be avoided, as they are difficult to make, and thus add considerably to the cost. The best effects are obtained from brackets which are not too elaborate, for it must be borne in mind that the design which is most pleasing on the drawing-board is often disappointing when erected.

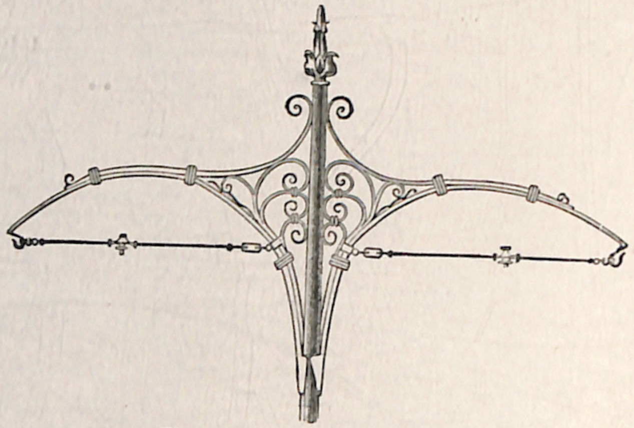


Fig. 102.—Double Bow-string Bracket

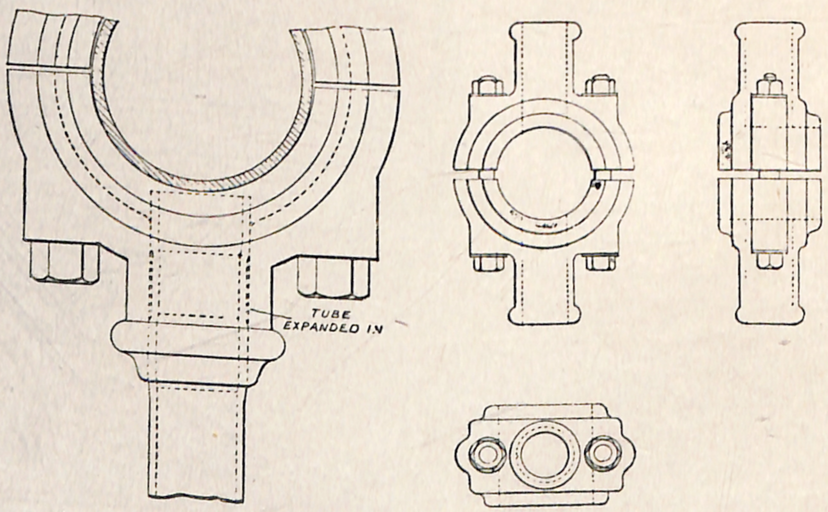


Fig. 103.—Split Collars for securing Brackets to Pole with Bolts

Owing to its height from the ground, much of the detail is lost, and the bolder, more simple designs are most effective. Another mistake that is frequently made in bracket design is the use of metal of too light a section, $\frac{3}{8}$ or $\frac{1}{2}$ inch by $1\frac{1}{4}$ inches being employed. The effect of this thin section is to obscure the detail, as when it is against the sky it is almost invisible. Also, unless looked at from exactly the right point, the curves of the two edges do not coincide, and this causes them to appear untrue. It is much better to make the scroll-work of metal having a section nearly square, even if no more metal is used; in fact, the circular section might be used in some cases to advantage.

Where span wires are used, it has now become customary to place on the top of the pole a small scroll-work bracket, which has the effect of subduing the extremely severe lines of the pole (fig. 104). These span-wire brackets usually extend 18 inches from the pole on each side, and the span wire is attached to one end of the bracket arm. There is no advantage in using this except its improved appearance.

As before stated, the flexible type of bracket suspension is essential to smooth running. This in effect is the conversion of the overhead system into span-wire work as far as the support of the actual wires and insulators is concerned. With the bow-string type of bracket it is accomplished by attaching a small length of steel cable to each end of the bow, forming, in fact, the bow-string (fig. 102), which is always provided at one, and sometimes at either end with a suitable screw-bolt for putting the requisite tension on the cable.

In the case of the straight bracket arm it is usual to clamp to the

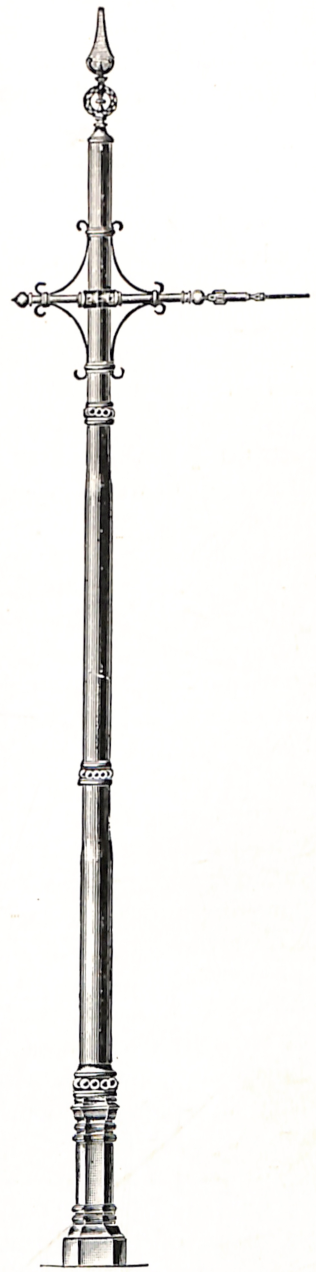


Fig. 104.—Side Pole and Span-wire Bracket

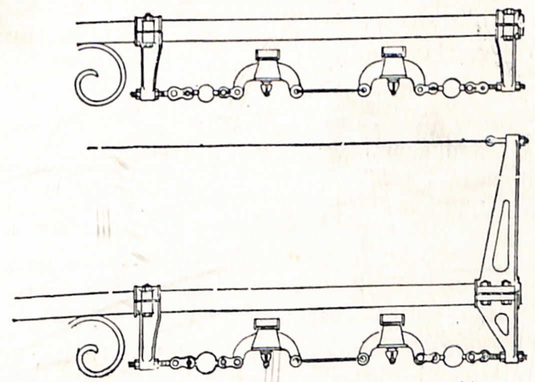


Fig. 105.—Flexible Bracket Suspension, with and without Guard-wire Support

pipe forming the bracket two lugs of suitable depth and design (fig. 105). These are placed at a convenient distance apart, according to the length of the bracket, usually from 2 feet 6 inches to 3 feet 6 inches, and the lower end of these lugs is provided with a screw for putting the tension on the cable. The top of the clamp holding these lugs is sometimes extended 1 foot to 18 inches upwards, in order to carry the guard wires where required.

Steel Cable.—The use of a stranded steel cable for supporting the trolley wire and insulators has now become universal, the solid steel wire having been abandoned.

A steel cable is usually of seven strands and galvanized. The minimum size which should be used is 7/14, and it will, of course, be necessary to increase this size at points where there is an extra heavy stress. The breaking stress of the smallest size should not be less than 2500 lbs. In calculating the size of cable required a liberal factor of safety should be allowed, usually 5 to 6.

The galvanizing should be of the best quality, and the wire should be capable of being wrapt around its own diameter and unwrapt without the galvanizing showing signs of cracking. In addition to the galvanizing, special means should be taken to protect the wire from the corrosive action of smoke, chemical fumes, or rust. It is nearly always considered sufficient to pass the end of the cable through the eye of the strain insulator or hanger, and then either nozzle off the wire or make a Britannia joint; but owing to the vibration of the entire overhead system, and the tendency of water to collect at this joint, it cannot be depended upon for more than about five years. Therefore at every point where steel cable is attached to an insulator or hanger it should be passed around a galvanized or brass heart-shaped thimble and spliced or nozzled off. The Britannia joint is not advisable, as it has a tendency to soften the wire.

In a bracket system it is good practice to make all the spans for the flexible suspension in the shop, of standard lengths, and then saturate them thoroughly with P. & B. or other waterproof compound. In spans extending across the street, or for pull-offs or anchors, this method is not practicable, but after the joint is made around the thimble it should then be saturated with the same compound, and at such time during the carrying out of the work as is convenient be painted throughout its entire length. These precautions are particularly necessary in span-wire work and with long pull-offs and anchors, as if one of these wires fail it usually is of sufficient length to curl around the trolley wire and fall into the street, which may cause a serious accident.

Trolley Wire.—This is now practically always made of hard-drawn copper wire, although silicon-bronze and phosphor-bronze have been used to some small extent Although these latter have a much higher tensile strength than the hard-drawn copper wire, their conductivity is much less, about 60 per cent, and they are also much more troublesome to handle, so that their use has not become very general.

The following are the sizes and particulars of the trolley wires in most common use:—

TABLE B

Standard Gauge.	Diameters in Inches.	Sectional Area in Sq. Inches.	Weights in Pounds.		Resistances per 1000 feet in International Ohms.	
			1000 feet.	Mile.	At 60° F.	At 75° F.
0 000	0.400	0.1257	484	2557	0.06363	0.06567
000	0.372	0.1087	419	2212	0.07357	0.07593
00	0.348	0.0951	367	1935	0.08407	0.08676
0	0.324	0.0824	318	1678	0.9698	0.10009

The larger size necessitates a considerable increase in the strength of the pole, span wires, and insulators.

The trolley wire should have an electric conductivity not less than that specified for hard-drawn copper in the British Engineering Standards, and should be perfectly cylindrical in section, and free from scratches, flaws, and other defects. It can be obtained in any reasonable length. It is usually put up in mile or half-mile reels. The former is preferable, and it is also an advantage to have the reels run somewhat over a mile, 2 or 3 per cent. The requirements of the Board of Trade demand that the trolley wire shall be divided into half-mile sections, and it is not always possible to get these exact; they frequently run a bit short or a bit over, and there must be a certain amount of allowance made for dip in the spans, and it is easier to run out two sections together than to have to mount a fresh reel for each section.

It is not good practice to allow joints in the work, either by means of a splicing sleeve or a splicing ear, although both are often used. It is difficult to get these joints made in the street to run without sparking, and consequently in time the trolley wire is liable to be weakened at these points.

There have been a number of different sections of trolley wire tried, such as "figure 8", "notched", and "trefoiled", the idea of these being to allow the use of mechanical ears and still have a smooth running surface for the trolley wheel. There is, however, difficulty in preventing these wires from twisting between the points of support.

Trolley wire should be delivered upon drums having as large a diameter as possible, not less than 3 feet. It should be reeled perfectly true and even, and free from kinks and sharp bends.

Ears.—These are of two general varieties, the mechanical ear and the sweated-on ear. The mechanical ear is one which is made to wholly or partially enclose the trolley wire, and holds it by friction. There have been a very large number of these designed and patented, and a few of the principal types are shown (fig. 106). They are very much easier to put up than the soldered-on ear, and considerably reduce the cost of labour in building a trolley line, but as yet none of them have been so designed that they will run without sparking. In order to get sufficient strength to grip the trolley wire they are usually made heavy and rigid, and the consequence is that in time the trolley wire is likely to break off at the ear from continual flexure. They are useful, however, for emergency repairs, and they may also be used to advantage in complicated junctions to hold the wire in place temporarily until the exact position of the ears can be determined.

The sweated-on ear is made in several designs and lengths, but the

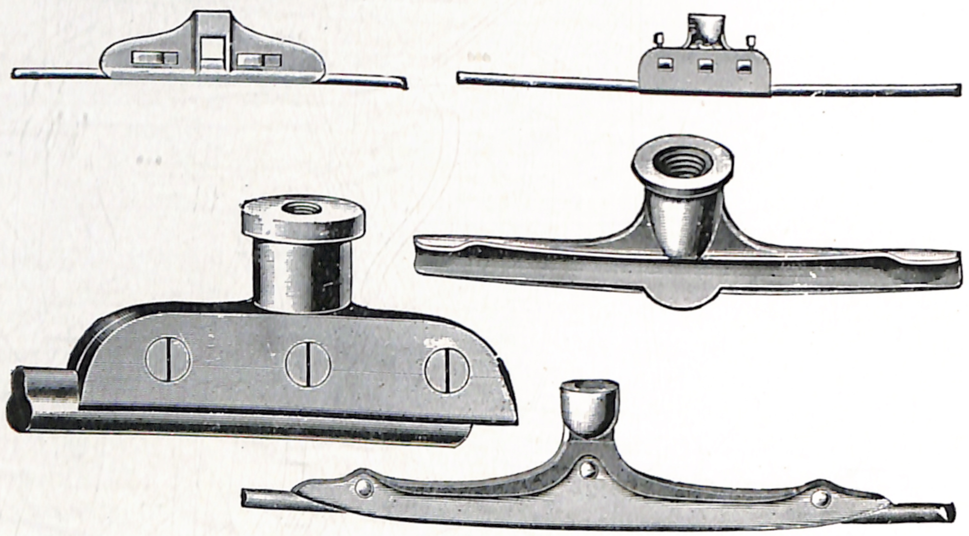


Fig. 106.—Various Types of Mechanical Ears

difference is chiefly in detail. The most usual lengths are 15, 18, 24, and 36 inches. In some cases the ears encircle about 180 degrees of the section of the trolley wire.

Another pattern is provided at each end with wings about ¾ inch long that nearly encircle the trolley wire (fig. 107). A still better form of ear for heavy work is one that encircles about 240 degrees of the trolley wire throughout its entire length. These are known as deep-groove ears, and are frequently ribbed.

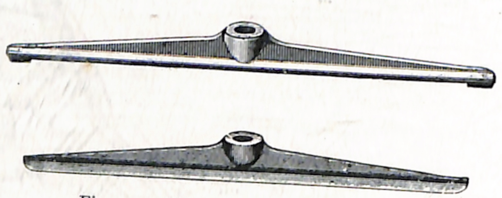


Fig. 107.—Winged and Deep-groove Ears

All ears should be drawn down fine at the ends, as it renders them more flexible, and allows them to take up a slight curve in either the vertical or the horizontal plane, thus avoiding the sharp angle produced by the mechanical or rigid ear. It in fact forms a parabolic curve, which the trolley wheel takes with a maximum of ease.

Ears should always be delivered thoroughly tinned on the inside. 15-inch ears without wings, and with a shallow groove, may be used on straight lines with No. 0 trolley wire; but 18-inch ears with small wings should be used at the curves, and it is much better to use ears with wings exclusively.

For the larger size of trolley wire the deep-groove ear is more suitable, and may be with advantage increased to 18 inches in length on the straight

and 24 inches on the curves; 36-inch ears are needed in comparatively rare instances, although on some tramways they have been used on all curves.

This tendency to increase the length of the ears beyond 24 inches is wholly unnecessary, as the gain in smoothness and certainty of running is not commensurate with the extra cost entailed by the very heavy insulators and span wires required. This to a certain extent means the strengthening of all the overhead work to correspond.

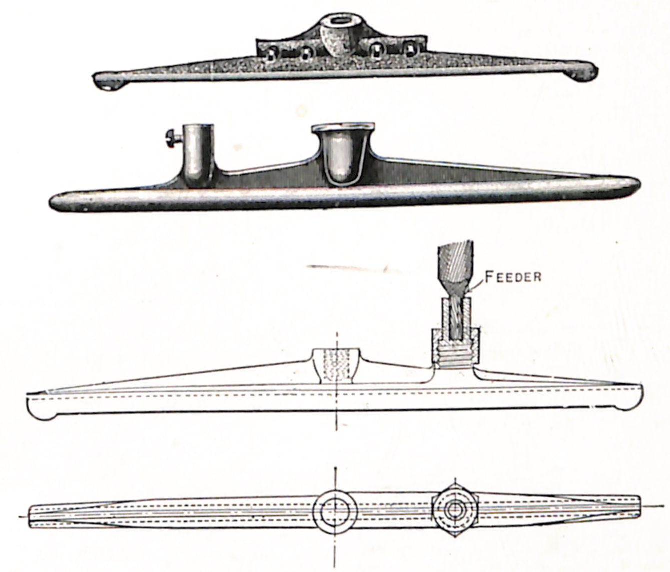


Fig. 108.—Types of Feeder Ears

Feeder Ears.—A certain number of ears designed to allow the trolley wire to be fed at desired points will be required. Some types of these are shown (fig. 108). A feeder ear should be so designed as to have ample contact area between the ear and feed-wire, which contact should be perfectly secure and easily detachable.

Splicing Ears.—Splicing ears are usually made as shown (fig. 109), although there are numerous other designs having slight differences. It is of great importance that the fine end of the ear should be carried out to a good length, and the ear should have considerable depth and be as thin as the required strength will allow. It is somewhat difficult to get these splicing ears to run smoothly, as, owing to their great weight, they form a more or less rigid spot in the line, which is apt to make the trolley wheel spark. It is better practice to avoid the use of them as far as possible, as this can be frequently done without excessive waste of trolley wire by the exercise of a little care in arranging the lengths of the sections and in the selection of reels of wire of proper length. Splicing sleeves are sometimes used (fig. 110), but they are not recommended except for emergency work.

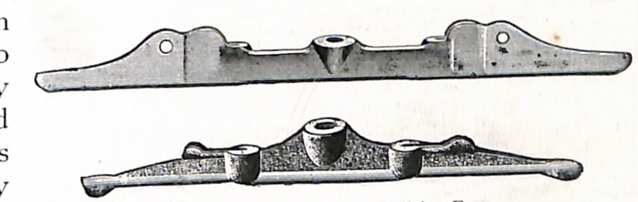


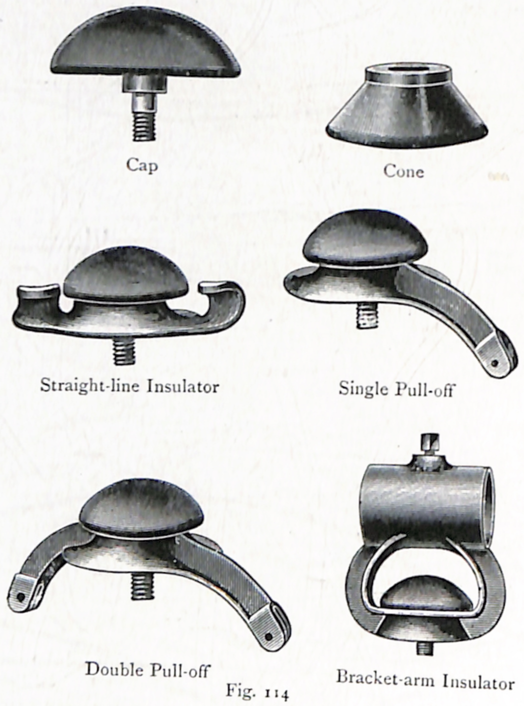
Fig. 109.—Two Types of Splicing Ears

Hangers and Insulators.—The use of hangers is to afford support for the insulation, and to afford a means of attaching the insulator to the span wire or brackets. The requirements of a hanger are that—

the previous types described; but if the cap is made of vulcanite or kept well painted it is a very satisfactory form of insulation, and is to a large extent free from the defect of the West-End type.

Types of rigid bracket hangers are shown (figs. 111 and 114). Secondary insulation is obtained by the use of a sleeve of insulating material slipped over the bracket arm. This rigid type may be used for slow speeds, but is not to be recommended.

It is now usual practice to run two trolley wires over the entire system—on single track as well as double. Where this is done on single track the two hangers are sometimes cast in one piece, as is shown (fig. 115), but this brings the trolley wires rather closer together than is usually advisable, and if the distance were increased the weight of the fitting would be too heavy for general use.



Cap — Cone — Straight-line Insulator — Single Pull-off — Double Pull-off — Bracket-arm Insulator

Fig. 114

Another type of hanger is shown (fig. 116) which consists of a heavy yoke with a globe insulator at each end, and the ear bolted to the centre

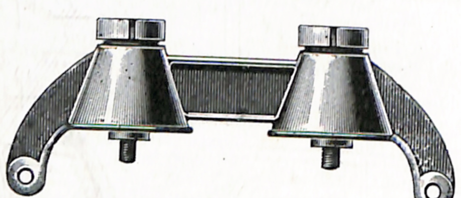


Fig. 115.—Double West-End Hanger

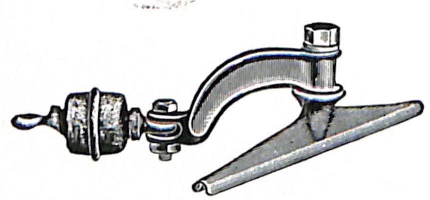


Fig. 116.—Single Giant Pull-over

of the yoke. This type has some advantages for certain classes of work. It is not as neat in appearance as the West-End type, but has much

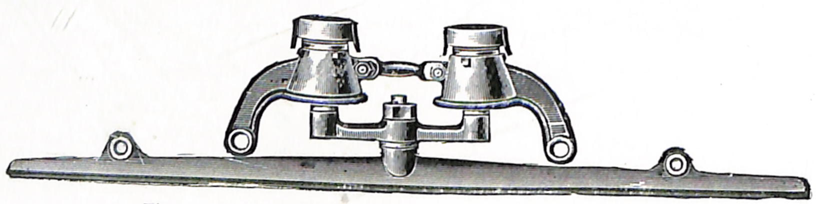


Fig. 117.—Double West-End Pull-off for Points of Extra Stress

greater strength, and can be used with advantage under conditions where the stresses are too great for the West-End bolt, and if a suitable type

of globe strain insulator is used and care taken to keep the insulators well painted it will give most satisfactory results.

Another method of dealing with points of exceptional stress is shown (fig. 117). In this two West-End bolts and hangers are used in such a way that the pull is distributed between the two.

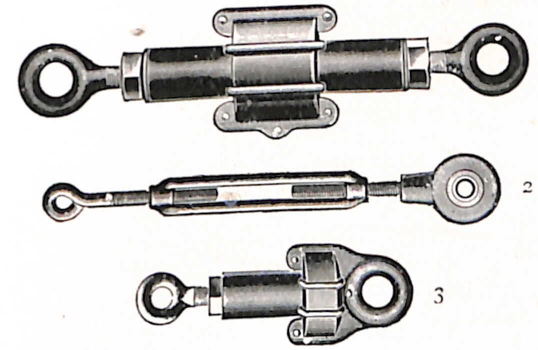


Fig. 118.—1 and 3, Brooklyn "Strain" Insulators. 2, King Insulated Turnbuckle

"Strain" and Globe Insulators.—These are used chiefly for secondary insulation, at the terminals of a line and for pulling frogs and crossings into position. The "strain" insulators are always provided with some arrangement for putting tension on the wire to which they are attached. They are of several types. The most usual are the Brooklyn, either single or double according to circumstances, and the King insulated turnbuckle (fig. 118).

The Brooklyn is a very efficient form of tension device, and is usually made entirely of bronze, and is to be recommended for span wires or anchorages on first-class work. The King turnbuckle is an efficient insulator with a considerable range of adjustment, and is very useful in span-wire work, but being made entirely of iron it is apt to rust, and cannot be adjusted after it has been in place for some time.

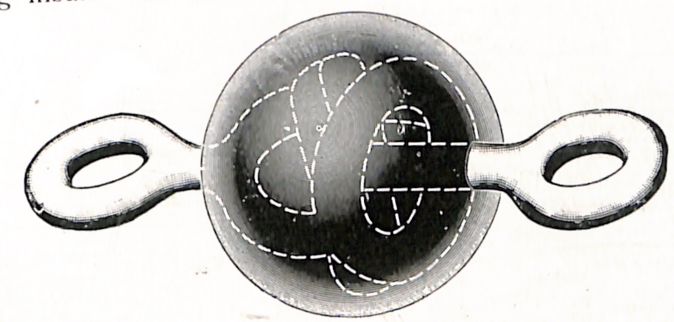


Fig. 119.—Globe "Strain" Insulator, showing Internal Links

Globe Insulators.—The globe insulator is made as shown (fig. 119). It is composed of two eye-bolts with a peculiarly-shaped ring and hook on their respective ends. These are interlocked and embedded in a globe of insulated material. They are made in several sizes, and designed for several different types of attachment.

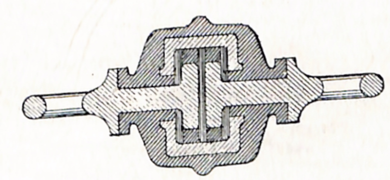


Fig. 120.—Section of Giant "Strain" Insulator

Another type of globe insulator is also shown (fig. 120). In this case it will be noticed that the insulating material is in compression between flat surfaces. In this type the portion of insulation in compression is sometimes made of the usual plastic moulded composition, and in others of sheets or cut mica, and the whole arrangement is afterwards moulded into insulating material, usually in elliptical form.

Another type, which also has its insulating material between flat surfaces, is shown (fig. 121). The result is arrived at in a slightly different way, and, being made up entirely of drop forgings, should have greater mechanical strength for a given weight, but does not appear to be quite so good electrically as the cut mica. This second type is much preferable to the first, and is much more durable. Excellent results can be got from simple porcelain globes with circumferential grooves at right angles to one another to hold the strain-wires.

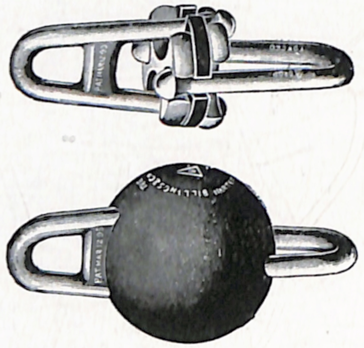


Fig. 121.—Globe "Strain" Insulator and Details

Bridge hangers and car barn hangers are shown (fig. 111), and their uses and advantages dealt with later on.

Section Insulators.—Under the Board of Trade regulations, and also for convenience in working, it is customary to divide the trolley wire up into sections of approximately ½ mile in length, and in order to accomplish this a section insulator must be used, which will preserve the mechanical continuity of the line and running surface for the trolley, and at the same time insulate the respective sections from each other. A number of designs for accomplishing this are shown.

There are two methods used for preventing the current from following the trolley wheel from one section to another, and thus forming an arc—the long-break (fig. 122) and the divided-arc system (fig. 123). The former is in the most general use, and is accomplished by the insertion in the section insulator of an insulating strip 8 or 10 inches long, upon which the trolley wheel runs. The strip is usually made of hard wood or fibre, and, as it wears in time with the passage of the trolley wheel and with sparking, it is designed to be readily renewable. In the divided-arc

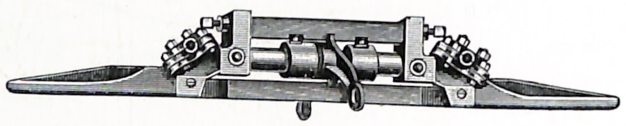


Fig. 122.—Section Insulator, Gate Type Long Break

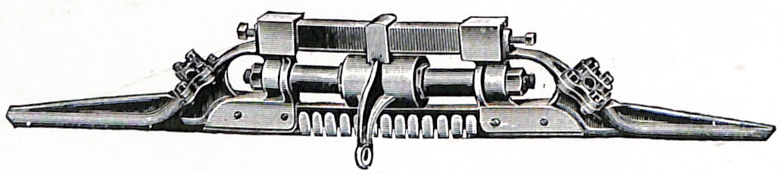


Fig. 123.—Section Insulator, Divided-arc Type

principle a number of small metallic sections are bolted together, insulated from each other at the top end, and separated at the bottom by an air-gap, usually from ⅛ to ¼ inch in extent: the arc which tends to follow the trolley wire is divided up into these small gaps, and goes out without trouble. These are more expensive, and do not seem to present any particular advantages over the other types. There is no great difficulty in

training the motormen to shut the current off and coast under these section insulators, in which case the renewal of the insulating strip is very infrequent, and in any event is inexpensive. Another type designed to avoid the necessity of shutting off the current when passing under is shown (fig. 124). This type will be found useful on gradients.

The most usual form of section insulator is what is generally known as the gate type (figs. 123, 124, and 125), in which the centre member is in tension and the top member in compression. This latter member is sometimes made adjustable in length by means of set-screws at the ends. The bottom member

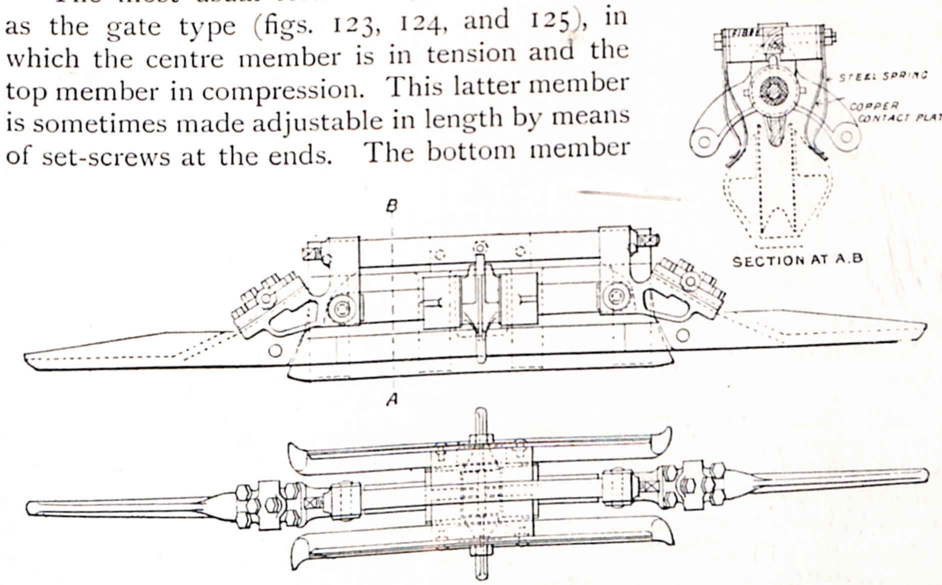


Fig. 124.—Continuous-feeding Section Insulator

of the gate is the renewable wearing-piece above referred to, and does not take any of the stress. This type of insulator is one of the straight under-running varieties, which may be worked at higher speed than those of the fish-belly type. The latter can, however, be made less cumbersome in appearance, as the stress on it is a straight pull. Section insulators should always be so placed that the stress on them is a straight pull, as they

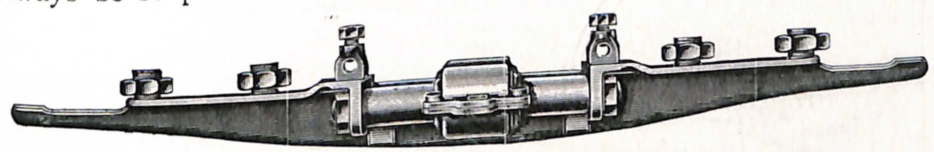


Fig. 125.—Hewer's Section Insulator

have little or no lateral stiffness, and if they are used as pull-overs they are sure to give trouble.

Hewer's section insulator (fig. 125) is of the fish-belly type, and so designed that the stress is taken by two bolts placed some inches apart in the same horizontal plane as the trolley wire. This type has considerable lateral stiffness, and, by making the ears long and fine, might be used on a decided curve without difficulty.

Section insulators are furnished with terminals at each end, so that they can be used as feeding-in points. These terminals are also useful if it is desired to put on a jumper to connect the trolley wires to each other. Two general types of terminals are used—one a socket with one or more set-screws, and the other holding the wire in a clamp, the cap of which is held in place by a number of bolts. In the first type the set-screws are apt to work out from the vibration of the trolley wire, and make a loose contact that will arc and heat, or else release the feed-wire.

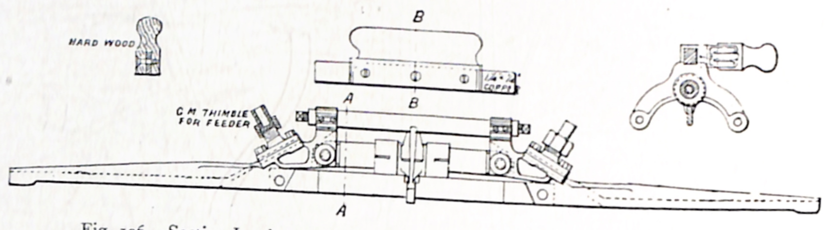


Fig. 126.—Section Insulator with Short-circuiting Switch and "Union" Terminals

The clamp is much more secure, but may be troublesome to disconnect in a hurry, as is often necessary when working.

A modification of the gate type of section insulator to overcome these faults in regard to the terminals is shown (fig. 126). This is provided also with spring contacts for the insertion of a jumper without disconnecting the feeding-in wires. The ears have also been lengthened to make a quieter-running insulator.

Owing to the extra weight of the section insulator, particular care should be taken to have its suspension flexible, and the ears holding the trolley wire long and thin, to compensate for this.

Fig. 127.—Section of Bell Insulator

Fig. 128.—Terminal Clamp

Bell Insulator.—A useful type of bell insulator is shown (fig. 127). They can be fitted with any desired form of terminal at either top or bottom, and are sometimes useful when it is desired to keep two adjacent wires from coming in contact by swinging together.

Terminal Clamp.—It is advisable at the end of a trolley line to secure the wire in some form of a clamp as shown (fig. 128). If the stress is not

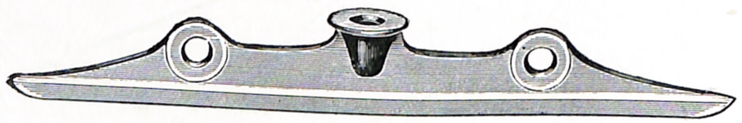


Fig. 129.—Anchor or "Strain" Ear

great a simple eye can be bent up in the end of the trolley wire; but the copper eye, being of soft metal, is liable to wear through in time.

Anchor Hangers.—In most cases it is preferable to attach the anchorage wires to the hanger instead of to the ear (fig. 129), for an anchorage attached to the ear is very apt to foul the trolley wheel, and also has a tendency to kink the trolley wire. If a very heavy stress on the anchorage

is unavoidable it is best to use a type which distributes the stress between two bolts as shown (fig. 130).

In some cases it may be useful to provide the trolley wire with a protecting sleeve 3 or 4 feet long. This is slipped over the trolley wire close to the section insulator or frog, or other point where especially heavy wear is expected.

Rosettes.—Where it is possible to obtain permission to attach rosettes to the faces of the buildings along routes it is of considerable advantage to do so, and even if this cannot be done to a large degree there are many cases where they can be used for pull-offs or special purposes, and thus save a pole, even if it is not desirable to erect any length of line by this suspension. Types are shown (figs. 98 and 99). These should be provided with from two to four bolts for letting into the wall. If the walls are sound, the smaller type with the holes close together can be used;

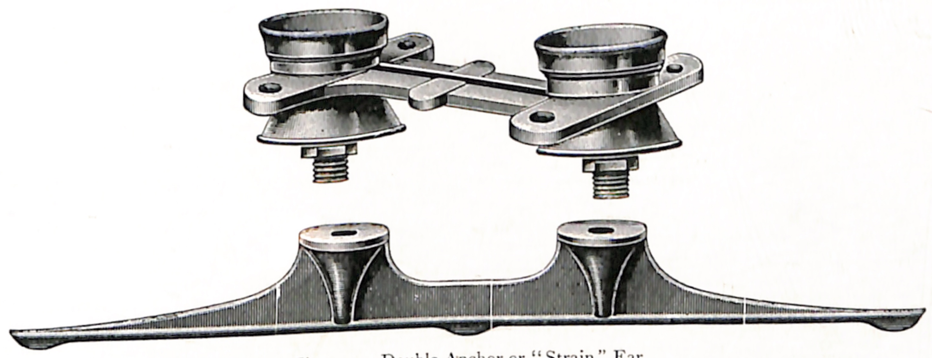


Fig. 130.—Double Anchor or "Strain" Ear

but if the stress is very heavy, or the wall is weak, it is preferable to use rosettes with a large back-plate, so as to distribute the stress over a larger portion of the wall. The rosette should be designed to allow a certain amount of adjustment, to permit the span wire to take up its proper direction, and all rosettes should be provided with a rubber buffer to act as a sound damper to absorb the vibrations from the span or pull-off wires.

Frogs and Crossings.—Frogs may be divided into two general classes: those designed for working with a fixed trolley head only, and those specially designed for use with a swivel trolley head.

The rigid trolley head will work with any type of frog, provided the frog is set in the correct position, but it is generally used with what is known as the fixed frog, which is shown (fig. 131). These frogs are rigid castings, and it depends entirely upon their position which wire the trolley wheel will follow, the principle being to place them so that when the car takes the branch track it will drag the trolley wheel along the side of the casting and cause it to follow the proper wire. They are classified as right, left, equilateral, and three-way. The last-named is only used in very special circumstances, and is not to be recommended, as it will not work with anything approaching certainty except when worked as a trailing frog. The other frogs will work with practical certainty as trailing frogs and a very considerable degree of certainty facing, if kept correctly set.

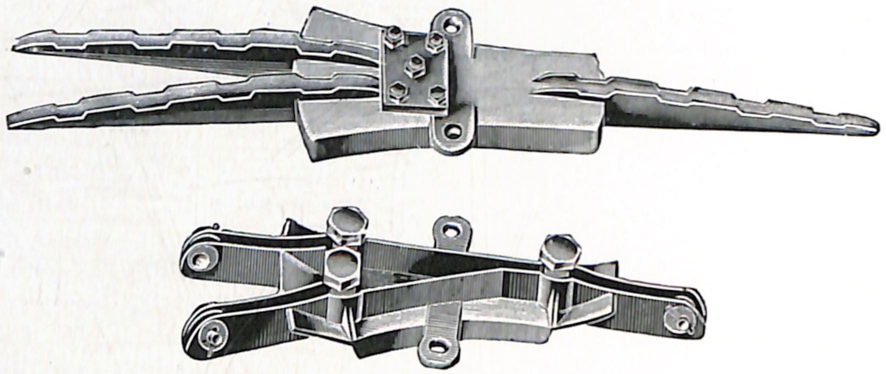


Fig. 131—Frogs for Fixed Trolley Head

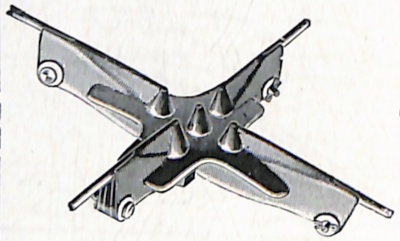


Fig. 132—Fixed Crossing for Rigid Trolley Head

Fig. 133—Adjustable Crossing

Fig. 134—Double Level Frog

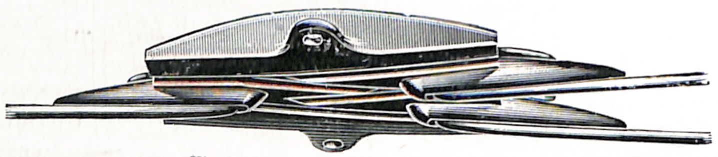


Fig. 135—Fixed Frog for Swivel Trolley

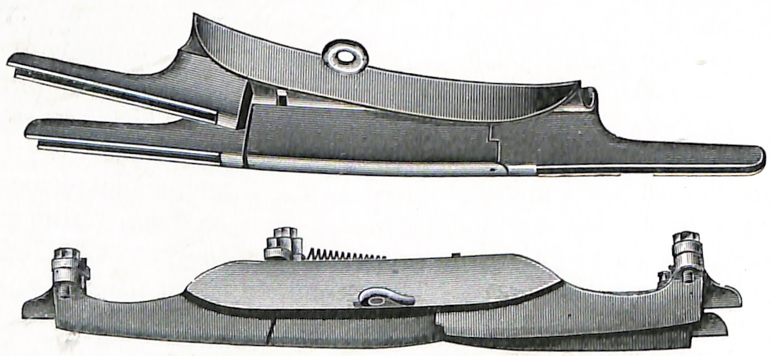


Fig. 136—Two Types of Mechanically-Moved Frogs

Frogs and Crossings

Crossings are of two general types as shown—the fixed (fig. 132) and the adjustable (fig. 133) crossings. The adjustable is preferable, except perhaps for right-angle crossings and extremely sharp angles. The principle upon which these work is easily seen from the illustrations.

Crossings should preferably be placed so that neither of the wires changes its direction when passing through, but with a fixed head they will work with a fair degree of satisfaction with a considerable angle in one or both of the wires.

All frogs for the fixed trolley head are now designed on the straight under-running principle. Two different types of fixed frog are shown, having different methods of attachment to the trolley wire (fig. 131). In one case the trolley wire fits into a groove in a long extension of the frog on the principle of an ear. The trolley wire is then held under a clamp, and the wings of the ears hammered over upon the wire.

In another type, which is more generally used, the frog is without ears, and the wire held in place by clamps. In this case the clamp is rounded off so as not to cause the trolley wire to break by being continually bent over a sharp angle.

With the introduction of the swivel-head trolley the above types of frogs and crossings were found to be unreliable, and various designs were made to secure certainty of action. The earliest type used was what may be described as the double-level frog (fig. 134). This frog deflects the trolley wheel by guiding it along an inclined runner until it has depressed the trolley wheel sufficiently for the flanges to clear the straight-through wire. When running trailing from a branch the reverse action takes place. When running trailing from the straight the trolley wheel pushes aside the guide runner of the branch and passes through, after which the guide runner is returned by means of a spring. If in running facing it is desired to proceed on the straight track, it is necessary to pull a cord which opens the switch and allows the trolley wheel to run through. This type will work automatically one way facing and both ways trailing, but it is open to the objection of all fish-belly frogs—that of not working well at high speed.

Another type for the swivel trolley is shown (fig. 135). This in general arrangement is something like the ordinary fixed frog, but instead of guiding the trolley wheel entirely by the groove, it does it part way by the groove and in the centre by the flanges, a ridge being provided in one place and two grooves in another. The fixed frog of this class will work automatically trailing, and can be arranged to run either way facing, but not both ways. Where it is desired to work both ways facing, a movable frog is used whereby the grooves and tongue are set for the correct way. This has to be done whether the frog is worked facing or trailing (fig. 136). In this design the use of both grooves and flanges as guides seems unnecessary, as, if the frog has to be moved for each car, it is simpler to guide the trolley wheel by the groove alone.

There are a number of modifications in detail of the above. Some of the movable frogs automatically set themselves for one track unless held in position for the other wire. Some accomplish this by a balance weight, and some by a spring, and some remain fixed in the position last used. A selection from various types can be used according to the service required of them.

Dawe's electromagnetic frog resembles fig. 136, but is fitted with a solenoid which is a shunt across the main circuit and which actuates the tongue. The shunt circuit is closed by a switch placed at a convenient

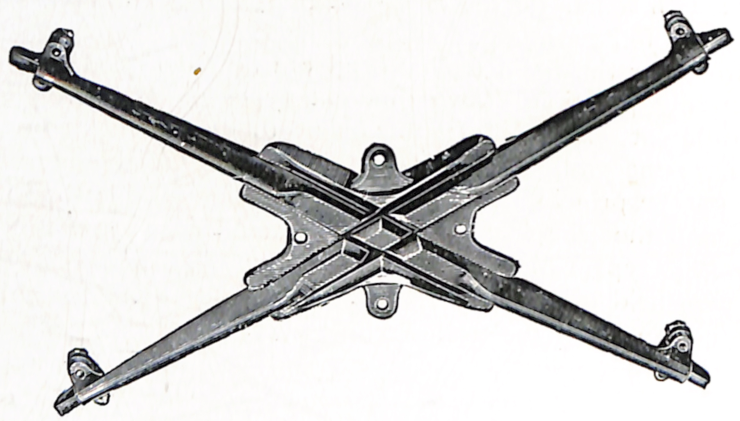


Fig. 137.—Rigid Crossing for Swivel Trolley Head

point, and worked by hand or by the movement of the permanent-way switch tongue, or by a cam struck by a projection on the passing car.

Crossings.—With the swivel-head trolley the crossings must be set perfectly straight, that is, the trolley wires must not change their direction in passing through the crossings. This can usually be accomplished by the proper adjustment of the pull-overs. No adjustable crossings have yet been designed for the swivel-head trolley, and it is necessary to guide the wheel over the fixed crossings by both flange and groove as above described (fig. 137). These can be obtained in a number of convenient angles, but it is the best practice to wait until the work is well advanced and have them made to the exact angle required.

Fig. 138.—Wurtz Lightning Arrester

A semi-adjustable crossing has been used with some success. It resembles fig. 133 in general design, but has the grooves for the flanges cut for one way, and after it is in position the grooves for the other direction are cut with a special tool.

Lightning Arresters.—It is necessary to protect the generators, motors, and the insulation of the line from effects of lightning. The two former are always protected by the use of lightning arresters in the generating station and on the cars; and to protect the insulation of the line, lightning arresters are often placed on a certain number of the poles. A lightning arrester for this purpose should be so designed that it is perfectly automatic, and should require no attention or resetting after it has acted. These arresters are all based on practically the same

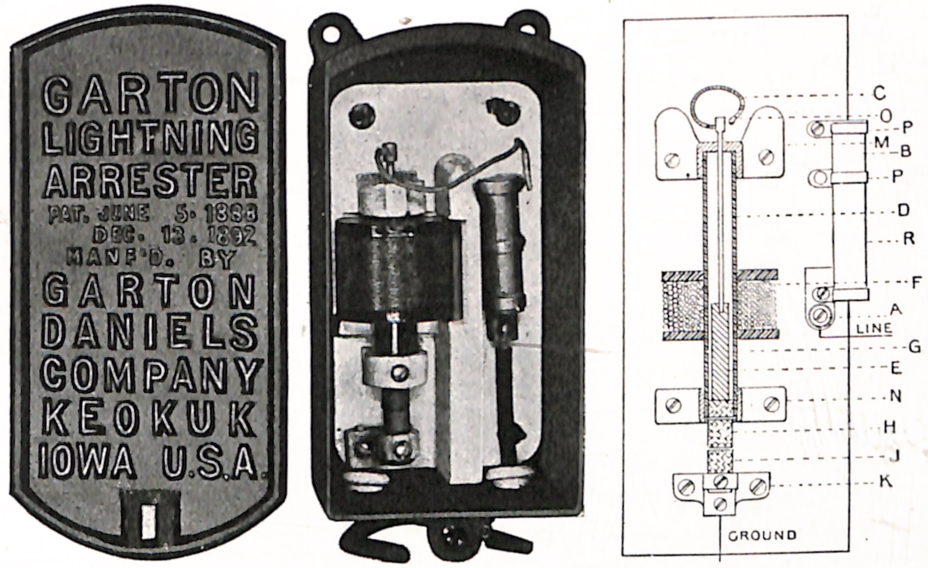


Fig. 139.—Garton Lightning Arrester

principle, that is, that the lightning discharge will jump across an air-gap, or a gap of high resistance, which is sufficient to afford a high degree of insulation as against the ordinary dynamic current. When the insulation of the gap has been broken down by the static discharge, and an arc established, the dynamic current will follow and maintain the arc, so means must be provided for promptly extinguishing this arc. In this latter particular lies the chief difference in the various makes of lightning arresters on the market.

The four types which have been most largely used for tramway work are the Wurtz (fig. 138), Garton (fig. 139), Shaw (fig. 140), and Ajax (fig. 141).

The Wurtz lightning arrester is probably the best on the market. It operates as follows: There is a gap of about $\frac{1}{2}$ inch between the electrodes, and this gap is filled with wood slightly carbonized on the surface. The arc-extinguishing device is based on the principle that to maintain an arc it is necessary that it should be fed with a metallic vapour, and the electrodes are made of special alloys which do not give off appreciable quan-

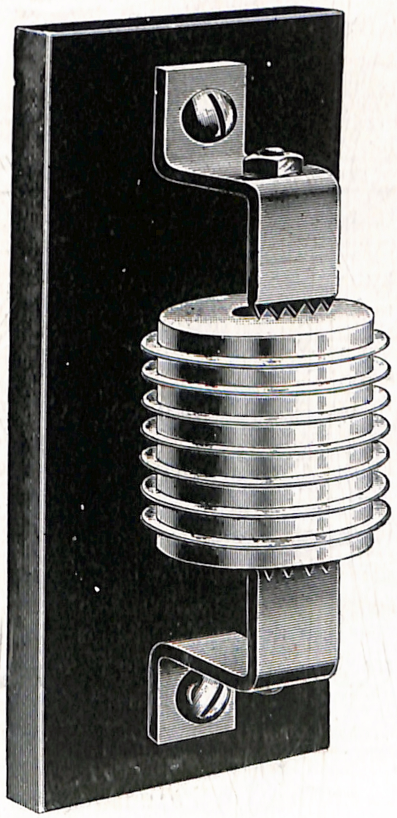


Fig. 140.—Shaw Lightning Arrester

tities of vapour. This arrangement is entirely automatic and needs absolutely no attention.

The Shaw lightning arrester is a pile of carbon discs separated by discs of insulating material, which extinguish the arc by dividing it into a number of short arcs which are not destructive.

The Garton lightning arrester (fig. 139) consists of an air-gap between carbon points H and J, a non-inductive resistance R in series with the gap, a magnetic coil F connected as a shunt across the resistance R. The arc is extinguished by the coil F, energized by the shunt current across R raising the armature E, which breaks the contact between E and H. The coil F, also acting as a magnetic blowout, immediately extinguishes the arc formed at this point. The arc having been extinguished, the armature E falls back into place, and the lightning arrester is thus reset.

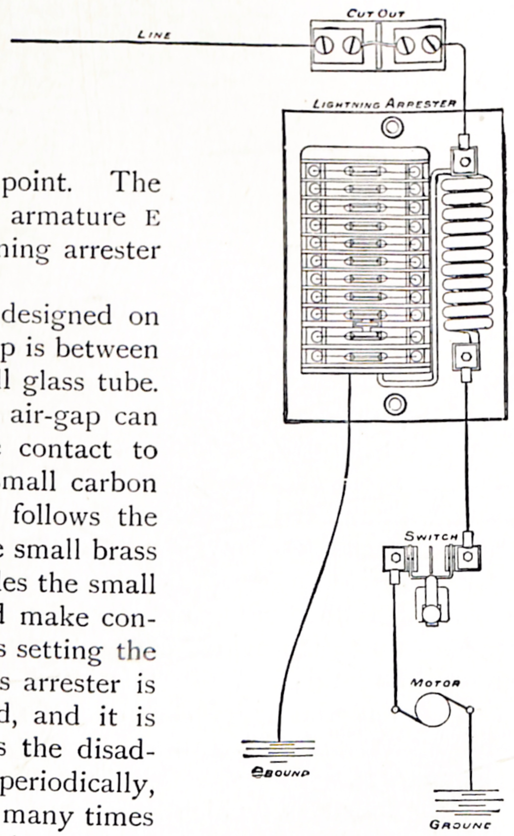


Fig. 141.—Ajax Lightning Arrester

The Ajax lightning arrester is designed on the magazine principle. The air-gap is between small brass wires enclosed in a small glass tube. Owing to its being sealed up, this air-gap can be made very small indeed. The contact to these brass wires is made by two small carbon balls. When the dynamic current follows the static discharge to earth, it melts the small brass wires as it would a fuse. This enables the small carbon balls to drop by gravity, and make contact with the next pair of wires, thus setting the arrester for another discharge. This arrester is automatic in action until exhausted, and it is refilled at a slight expense, but has the disadvantage that it must be inspected periodically, there being no means of telling how many times it has been in action. Consequently a slight carelessness on the part of the linesman may leave the line without protection. To render the action of lightning arresters more certain it is the usual practice, where possible, to place an impedance coil between the object to be protected and the lightning-arrester tap. This impedance coil usually consists of ten or twelve turns of heavy wire about a wooden core.

The number and location of lightning arresters required on a tramway must be governed by the frequency and violence of thunder-storms in the region. For English practice it is generally considered sufficient to place one in each section of trolley wire, usually about the centre. In fact, many engineers now omit them altogether. In most cases it is not possible to arrange an impedance coil, but this is not absolutely essential unless there are some local conditions that are not normal.

To face IV. 154

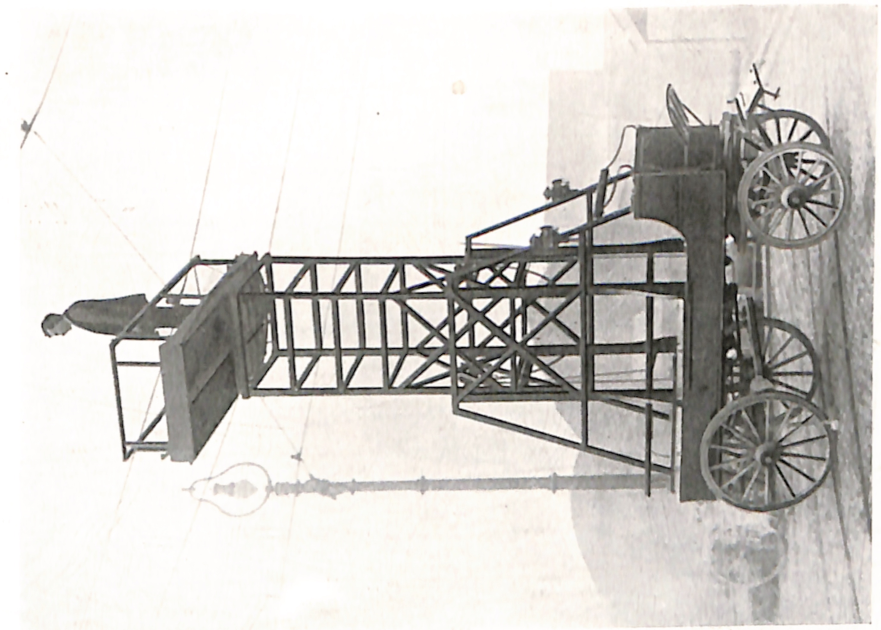


Fig. 143.—Collapsible Tower Wagon

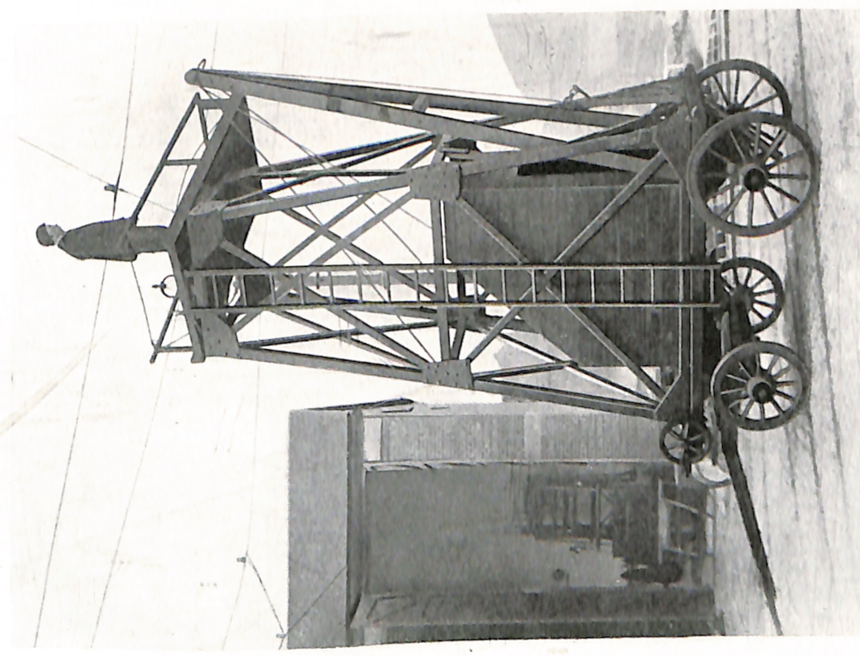


Fig. 142.—Fixed Tower Wagon

(36)

In tropical or mountainous regions each feeding-in wire should be provided with an impedance coil and lightning arrester, and if the feeding-in points are a considerable distance apart another lightning arrester should be placed between them.

The greatest care should be taken in providing suitable earth for lightning arresters. Where steel poles are used, the earth-wire of the arrester can be connected to the pole by means of a rail bond, either solid or plastic, and the base of the pole connected to the tram rail by another rail bond. If the pole is of wood, the wire may be carried down the pole and out to the rail and bonded to the same. If the permanent way is laid in very dry soil, or on wooden cross sleepers, it will probably be more desirable to use an earth-plate for earthing the arrester. This earth-plate should be of liberal dimensions; an old car wheel makes a very good one. The wire from the lightning arrester should then be bonded to the earth-plate, and the plate buried to a sufficient depth to obtain moist earth. A considerable quantity of charcoal or gas coke should be placed about the earth-plate to retain moisture.

Tools.—The following tools and appliances will probably be found sufficient for most classes of work:—

1 reel wagon.
1 fixed tower wagon (fig. 142).
1 collapsible tower wagon (fig. 143).
12 to 24 sets of digging tools, each consisting of:—
  1 digging bar, 8 feet 6 inches long, octagonal steel.
  1 digging bar, 5 feet long.
  1 auger, 5 feet long, 15 inches over blade (fig. 144).
  1 auger, 7 feet 6 inches long, 15 inches over blade.
  1 spoon (fig. 145).
  1 (grafting tool) spade with extra long handle.

12 picks.
12 shovels, No. 4.
4 rammers.
4 soldering-irons (fig. 146).
2 soldering-pots.
1 brazier or fire-devil.
2 U-shaped clamps for soldering, 3 feet 6 inches between jaws.
Pliers, 7 inches and 8 inches; gas, 8 inches.
1 pipe-tongs.
1 pipe-cutter.
Trolley-wire cutters.
2 hammers, 2-lb., and stone hammers.
2 sledges, 12-lb.
Chisels.
Files.
4 draw-vices. Heavy P.O. pattern.
Tool for putting up frogs (fig. 147).
1 tool for putting up straight-line hangers (fig. 148).
Spanner, Clyburn.
2 hack-saws and blades.

1 plumb-line.
12 "come-along" clamps (fig. 149).
1 special level for pole setting.
1 right- and left-hand strainer and coupling-screws (fig. 150).
6 lbs. of solder per mile of single wire.
Steel-tape measure.
2 ladders, rungs 9 inches apart, 24 feet long.
Acid jug and charcoal.
Vice-machine.
Vice-pipe.
2 screw-drivers.
2 sets $\frac{3}{4}$-inch blocks.
400 feet of $\frac{3}{4}$-inch rope.
2 sets $\frac{1}{2}$-inch blocks.
300 feet of $\frac{1}{2}$-inch rope.
4 wire draw-tongs (fig. 151).

A reel wagon usually consists of an ordinary heavy four-wheeled wagon, with a flat platform, and capable of carrying about two tons. Upon the platform is built a timber framework to carry a reel of trolley wire. Attached to the framework is rigged a brake, usually applied to the rim of the reel in order to put a certain amount of tension on the trolley wire, and to prevent the reel from running out too fast. A roller guide is also provided for the trolley wire to run out over. It is preferable to have the wagon as low as possible. If the line is a small one, it is possible to dispense with the reel wagon, and arrange the fixed tower wagon to carry a reel of wire, but it is much more convenient to have a separate wagon, and one can usually be hired for this purpose. Any ordinary heavy lorry will do, and the framework is easily attached to the lorry platform.

A very serviceable type of fixed tower wagon is shown (fig. 142). This, as will be seen, consists of a very heavy body with a framework erected on top of it. This framework carries a platform at a convenient height, depending somewhat on the height of the trolley wire, usually from 17 to 18 feet from the ground. The platform is provided with a railing at the top and also at one side with a hinged extension, as it is sometimes necessary to work over the track or over the footpath without interfering with the traffic. The lower part of the framework is boxed in so as to form a lock-up store-room for tools and supplies. The framework is also provided with a jib-crane, a winch, and tackle which is used for pole-setting. Another arrangement of crane can be used by pivoting the jib-crane at the bottom of the framework, and holding it in position with tension-rods. In this way the length of overhang may be made adjustable, which is sometimes convenient when the poles are not set exactly on the kerb.

A differential chain block and falls can be used in place of a winch. It is somewhat cheaper in first cost but much slower in action. The wagon should be provided with a powerful screw-brake. Sometimes the tower wagon must be made variable in height, for if there are railway

Fig. 145.—Spoon for Digging Post Holes

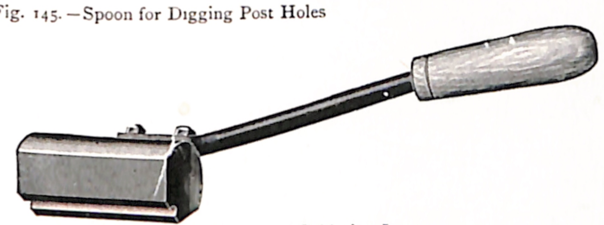


Fig. 146.—Soldering-Iron

Fig. 147.—Special Tool for putting up Frogs

Fig. 149.—"Come-Along" Clamp

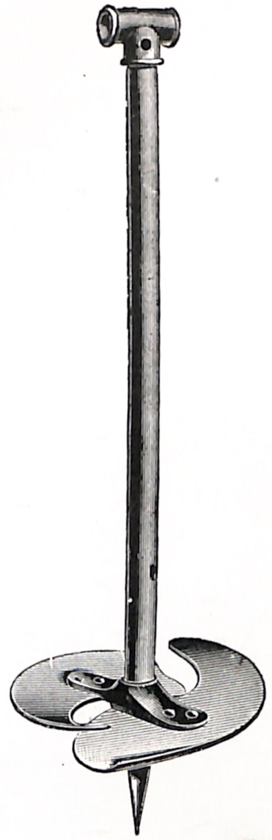


Fig. 144.—Auger for Digging Post Holes

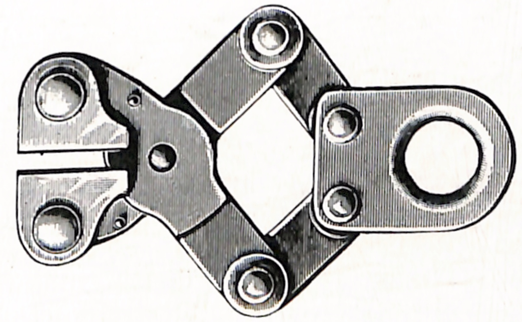


Fig. 151.—Wire Draw-Tongs

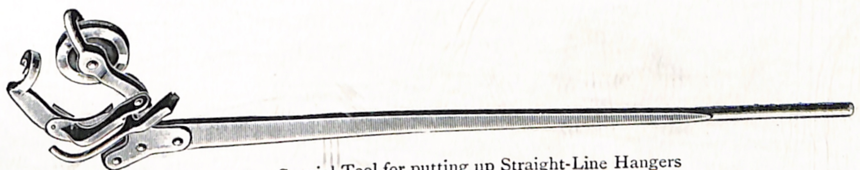


Fig. 148.—Special Tool for putting up Straight-Line Hangers

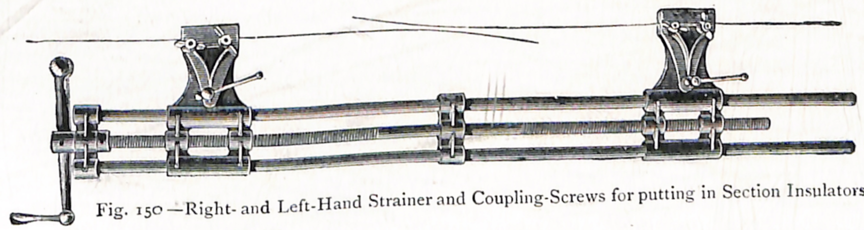


Fig. 150—Right- and Left-Hand Strainer and Coupling-Screws for putting in Section Insulators

Overhead Construction—Tools

bridges crossing the lines, it may be difficult to get a tower of standard height underneath them, as these bridges are frequently under 16 feet in height. This should be borne in mind in designing a tower wagon for any particular piece of work.

A very good type of collapsible tower wagon is shown (fig. 143), with a telescopic tower and a rotary and extensible platform at the top. This type of tower wagon is more useful for emergency and repair work after the line is built than in the original construction. It is made as light as is consistent with strength, and therefore has not the storage capacity for tools, &c., of the type previously described. Being of much lighter build, and constructed for rapid transportation, it is not sufficiently stable for very heavy work. Motor tower wagons for emergency work are greatly superior to horse-vehicles.

The quantity of digging tools required will depend upon the number of men it is intended to employ and the character of the ground to be excavated. The augers can be used in certain classes of soil with good

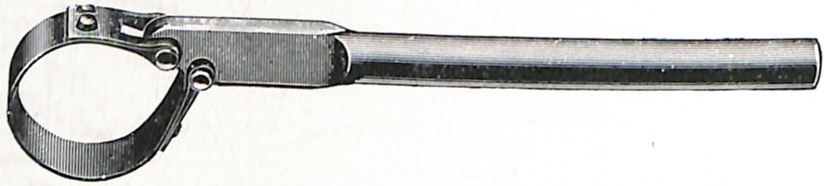


Fig. 152.—Special Tool for screwing up Insulating Bolts

effect, but are not of much use if gravel and stones are prevalent. The rammers are used for beating the cement into position after it has been placed in the holes, and it is often convenient to have one or more of them made semicircular or crescent-shaped. The soldering-irons should be as shown (fig. 146), and usually weigh about 12 lbs. apiece. There should be a good assortment of files, and as they are very rapidly spoiled by the solder when used for dressing down the ears, a number of float-files should be provided for this purpose. The draw-vices should be of the heavy Post Office pattern with key and ratchet.

A special tool for putting up frogs is shown (fig. 147), but it is not at all essential, and unless there are a large number to be put in, would not pay. A special tool for putting up straight-line hangers is also shown (fig. 148). This is chiefly useful for span-wire work, and if there are a large number of spans, can be used with advantage, but the work can be done with a couple of wire draw-tongs and a light block and tackle. For bracket-hangers with the short spans, it is usually easier to slack off the tension at the end, when the hanger can be slipped in by hand and the span wire tightened up again. The steel-tape measure should be about one chain in length, and it is also advisable to have 100 feet of linen tape in addition. The machine-vice should have about 5-inch jaws, and it should be so arranged that it can be readily attached to the heavy tower wagon. A pipe-vice is extremely serviceable where there is any bracket-arm construction, and should be of sufficient size to take the pipe used for this purpose. It should also be fastened to

the tower wagon. This last, together with the pipe-tongs and pipe-cutters, may be omitted if span wires are exclusively used. A special tool is also shown for screwing up the West-End type of insulating bolt, which can be used to advantage in most cases (fig. 152).

Setting Out Work.—It is first necessary to determine whether a swivel-head or rigid trolley wheel is to be used. This point having been decided, the next step is to set out the points of support, and then, if the engineer is free to make his own decision, to determine whether span-wire, centre-pole, or side-bracket suspension is preferable, and at what points.

There are certain fixed points, such as junctions, sharp curves, terminals, &c., which serve as a basis to work on. These having been settled and located on as large a scale plan as is available, the spaces between them should be divided up into approximately equal divisions. The maximum distance between supports allowed by the Board of Trade regulations is 40 yards. This is about as far as it is wise to go in practice, supposing these regulations do not apply, but spans up to 45 yards may be occasionally used without detriment to the safety of the line.

Upon the basis of 40-yard trolley spans it would be necessary to have forty-four supports to the mile, but in preliminary estimates fifty may be taken as a safe figure, and one easy to memorize and work with. It will be found on the average to be more nearly correct than forty-four, on account of extra poles required at junctions. It will also be found in practice that, in endeavouring to space out the poles at regular 40-yard intervals, a certain number of them will fall in the centre of cross streets or in front of doorways, where it is impossible to place them. As the length of trolley span cannot be increased, it is necessary to remove the pole to the nearest location that is satisfactory. This then becomes a fixed point, and the poles between this and the last fixed point should be respaced and made as even as possible.

In laying out work it is best to calculate on 38-yard intervals instead of 40, as it is very often of the greatest convenience to be able to move a pole a few feet one way or the other to avoid pipes or underground obstructions without respacing the whole section. It should also be remembered that it may be more advantageous to slightly reduce the spacing of the poles on curves of large radius or on steep gradients than to use heavier poles, as the former method distributes the stress of the curve over a greater number of insulators, which are the mechanically weak points in the construction.

The next step is to determine the size of the poles to be used under various conditions. Theoretically, it would be possible to calculate with a considerable degree of accuracy the stress to which each pole would be subjected; but it is not at all usual to have a survey of the tramways on a sufficiently large scale, and of sufficient accuracy, to do this, and in practice a few general rules, when coupled with a little judgment, will suffice. In doubtful cases the engineer should put in a pole of ample strength.

Some engineers prefer to use a great variety of sizes of poles, estimating, as accurately as their experience will permit, the stresses at various points. Others will adopt but two, or at the outside three sizes, and use them exclusively. In this latter case only the heavier types of pole are employed. The choice between these methods will be largely governed by the market prices of poles, but the general tendency now seems to be towards the second.

The location of the supports having been determined, the width of the roadway at these points should be ascertained, and also the distance from the kerb to the centre of the track or tracks, as these dimensions will determine the most suitable form of support to be used.

The Board of Trade require a minimum clearance of 15 inches from the side of the car to the pole, and as the pole cannot be located within an inch or two, it is necessary to allow at least a foot for thickness of the pole. This makes it necessary to have, for centre-pole construction, a distance between the centre of the tracks equal to 3 feet 6 inches plus the extreme width of one car.

It should be borne in mind that whatever type of trolley head is used, the closer and more nearly parallel to the centre of the track the trolley wire can be kept, the more smooth and satisfactory will be the working of the line. With a rigid trolley head the departure from the centre cannot exceed about 2 feet, and preferably should be kept within 1 foot; and as side brackets of over 16 feet are not to be recommended, it limits the width of street upon which side-bracket construction can be used to about 30 feet for single track and 24 feet for double. If two rows of side brackets are used, one on each kerb, it can be worked with double track on a 40-feet street. Beyond this width span wires are absolutely necessary. But this form of construction, with two rows of side brackets, is not to be recommended with the centre-running trolley.

With the swivel-headed trolley the line can be made to work with the trolley wire as much as 15 feet from the centre of the track. This extreme reach is not at all desirable, and it should be kept if possible within 6 feet, at which distance most excellent and satisfactory results can be obtained. This, with the use of a bracket not exceeding 16 feet in length, will work with single track in a 40-feet street. In the case of double track with a 17-feet bracket and 6-feet reach, a single row of brackets may be used in streets up to 35 feet in width, which width is sufficient to allow the use of the centre-pole form of construction. If centre poles cannot be used, two rows of poles and brackets will work up to a width of 50 feet, beyond which it would be much more satisfactory to use span wires.

On straight and level track the side stress on the pole is readily determined either for span or bracket construction. In centre brackets it is practically nothing. In span wires it can be determined by the application of the parallelogram of forces, assuming the weight to be half the weight of each of the adjacent trolley spans. In side-bracket construction it may be determined by dividing the height of the bracket above the ground by the distance from the pole to the trolley wire in feet, and dividing the weight of the trolley wire in half of each of the adjacent spans by the result. To this must be added the stress set up by the bracket itself, which will be the height of the bracket arm above the ground divided by the distance from the pole to the centre of gravity of the bracket, expressed in feet, and the weight of the bracket to be divided by this result; this is usually negligible. These stresses must be determined as they will represent the minimum, and to them must be added the stresses caused by the curvature of the line or the changes of gradient.

The following sizes of poles will usually be found satisfactory. It is assumed that in all cases two 00 trolley wires will be used, as this practice is now almost universal for both single and double track.

On straight and level track, for centre and short side-bracket construction, 350-lb. poles may be used, but a smaller pole than 500 lbs. is not recommended. For span-wire work 500-lb. poles may be used on streets up to 30 feet in width, if a moderate amount of dip in the span wire is permissible. It is not recommended that for span-wire work poles of less than 700 lbs. should be used for high-class and durable work.

The above stresses—500 lbs. for bracket work and 700 lbs. for span-wire work—should have a sufficient margin of strength to be used in all places where the curvature is not greater than the equivalent for a 10-chain radius, or where the brackets do not exceed 16 feet in length, or the gradients 1 in 20. If these figures are much exceeded, the strength of the poles should be increased. But in the case of span wires the poles on the inside of the curve need not be increased, and might even be made lighter than suggested, as they do nothing to hold up the weight of the trolley wire. If 000 or 0000 trolley wire is used, the poles should be increased to 700 and 1000 lbs. respectively. Any poles to which it is intended to attach anchors or bridles should be somewhat heavier, 1200 lbs. being about the minimum for an anchor and 1000-lb. pole for a bridle. Poles upon which it is intended to use section insulators are generally made heavier; the larger diameter of pole gives more room for feeding-in wires if used. Some engineers made it a practice to anchor the trolley wire both ways from a section insulator. Poles in the vicinity of junctions should also be made heavier, 1000-lb. poles being the minimum for this class of work, but 1500- and 2000-lb. poles must be frequently used.

If the stresses in a junction are self-balancing, somewhat lighter poles may be used than could be otherwise. Where the gradients are long and severe, or on the crown of a hill, it is often advisable, and sometimes necessary, to provide anchor-poles and anchorages to take the stress caused by the tendency of the trolley wire to slide downhill, which tendency brings a very heavy stress upon the supports approaching the summit.

Excavation.—The holes for the poles should be excavated to a depth of not less than 6 feet, and the size of the hole must depend upon the diameter of the pole and the nature of the soil. If the soil is firm, and the streets are paved and afford a good support at the surface of the ground, a hole very little larger than the diameter of the pole will suffice. If the soil is loose and sandy, or in made ground, it will be necessary to very considerably increase the diameter of the excavation in order to distribute the stress over a larger area. In some cases it may even be necessary to take special precautions to this end, namely, digging a trench 6 or 7 feet long at right angles to the direction of stress, and placing a piece of old rail 6 or 7 feet long at the back of the pole at the bottom, and a similar piece in front of the pole at the top, and embedding the whole in concrete. As a general rule three times the diameter of the butt of the pole will be a sufficient diameter for the hole. Some support must be provided at the foot of the pole to prevent its sinking into the ground farther than was intended, and a flat stone or cast-iron base-plate may be provided for this purpose. Another method is to prepare concrete discs by running the concrete into moulds about 18 inches in diameter and 6 inches thick, and placing these, when they are thoroughly hardened, at the bottom of the excavation; or 4 inches of concrete may be put into the bottom of the excavation and a piece of 2-inch plank placed on top of this. The method adopted will depend to some extent upon the locality and the materials available.

The poles should then be placed in the holes and given the necessary rake, and the whole of the excavation filled in with concrete thoroughly rammed. Care should be taken to finish off the top of the concrete in a slightly conical form and higher than the level of the street, where it joins on to the protective sheathing of cement round the pole.

Concrete.—The quality of the concrete may to some extent be governed by the character of the soil and the stress to be expected. If the earth is firm and the stress not excessive a cheap form of concrete may be used of eight or nine to one, and large stones may be employed, jammed in between the pole and the earth. In fact, if sufficient care were used, under these circumstances the pole could be set without any concrete at all, but the difficulty of getting men to properly tamp in the soil renders the use of concrete of some sort a necessity. If it is found necessary to increase the diameter of the excavation to distribute the stress, it then becomes necessary to use concrete of the best quality, not less than six to one.

Rake of Poles.—The rake of the poles must be determined in view of the stress they are to bear, and should be such that the stress will pull them up apparently straight, and should not, except in special circumstances, be greater than the diameter of the pole at its base. If it becomes necessary to increase this rake a heavier pole should be used, or the stress distributed among several poles. The reason for this limitation is that a pole, when it gets its trimmings on, does not appear to be bent if the curvature does not exceed the greatest diameter. There may be exceptional circumstances where it is not possible to follow out this rule, but they should be rare. It is preferable to give a pole too much rake rather than too little, for a pole that leans away from the stress does not convey an idea of weakness, while an inclination in the direction of stress gives it an appearance of falling over. This is, of course, purely an optical effect, but is one which is most severely criticized by the general public. Great care should be taken to give all poles visible from any one point an equal rake, and special attention should be given to poles that from their position can be readily compared with perpendicular lines of buildings.

It is sometimes necessary, where several wires are attached to a pole, to set it with a rake in the direction of the resultant stress. Where it is necessary to set a pole with the maximum rake it is frequently advisable to stay the pole in that position until the concrete has had time to set. This can readily be done by the use of a collar clamped on the pole 4 or 5 feet from the ground, the collar being provided with three pivoted legs like a tripod.

A special level for pole setting is provided with a cross bubble and a scale for measuring the inclination of the pole from the vertical, and is very useful in obtaining even results.

When the poles are being tested for acceptance it is advisable to plot a curve showing the deflection of the pole for different loads. This will be found useful in determining the exact rake to give to any pole.

Erection of Poles and Fittings.—The pole-setting itself is usually done by means of a derrick attached to the tower wagon, but is sometimes done by sheer-legs, and occasionally by manual labour, assisted by forked poles of various lengths. The former method is preferable, and in most general use. One tower-wagon derrick, with a gang of one foreman and six or eight labourers, should set from thirty to forty poles in the course of a day, it being assumed that the poles have been delivered in the neighbourhood of the holes. As forty poles represent some half mile of street, if they are set on both sides, or nearly a mile if set on one side only, one horse, cart, and driver will be needed to keep them supplied with concrete materials. A sufficient number of men should be provided to excavate the holes as rapidly as the derrick gang can fill them, and the size of this gang will vary according to the character of the soil. The men usually work in pairs, and two men will, under average conditions, complete a hole in two hours.

The poles should be allowed at least seven days for the concrete to set before being subjected to any stress. The bases, collars, and brackets should then be put on. In some cases the bases, if not excessively large, can be slipped over the pole before it is set, but if this is not practicable they will have to be lifted over the top by a light sheer-legs, and if not of great weight may be hoisted from a spar lashed to the framework of the tower wagon. Collars are next slipped into position, and then the brackets are put on. The tower and extension to the platform will be found necessary for this work. The main portion of the bracket is lifted by the tackle into position, and the back half of the split collar is then put in place and the collar bolted together. It is advisable to coat the inside of the split collar with a mixture of putty and white-lead to prevent moisture lodging between the collar and the pole. This applies to all split collars either on the pole or bracket arm. The collar being in position the truss rods are next adjusted so that the bracket arm is at a slight angle above the horizontal, and are adjusted more accurately after the trolley wire is in position. The remaining portions of the bracket are now fitted on. In the case of span-wire brackets the method is the same, but as they are simpler and lighter, and have no truss-rod adjustment, they can sometimes be done from ladders or from a smaller tower wagon.

The pole collars covering the joints should next be bedded in putty and white-lead, the finial put into the top of the pole, and preferably secured by a grub-screw. It is advisable that the top of the pole should be covered while the concrete is setting, as it is not desirable to have any quantity of moisture inside of the pole. The base of the pole should be set concentric with the pole, bedded on cement mortar, and the annular space between the pole and the top of the base filled with melted lead, or a suitable metallic cement. This fixing of the pole bases is preferably left until after all the stresses are on the poles.

If it is intended to use flexible bracket construction the flexible suspension hangers and secondary insulation should be fitted to the bracket arm at its time of erection. In this case it is better to make up the flexible spans in standard lengths, with the insulators attached and hangers in place, in a convenient workshop, as this work can be done there more efficiently than in the street. If rigid bracket suspension is to be used there is no particular advantage in putting up the hangers before the trolley wire is strung. In span-wire work for straight-line insulators the span is first put up and the insulator sprung in by a special tool shown (fig. 148).

If curve hangers are to be used they should be attached to the span wire. A "come-along" is then clamped to each end of the wire, and the span pulled up with a block and tackle or a P.O. vice, and the insulators plumbed for their proper position, keeping in mind that the stress of the trolley wire will pull them somewhat towards the inside of the curve. When they have been brought to the desired location the ends of the span wires are made fast to the Brooklyn strain insulators, and any fine adjustment is afterwards made by means of these turnbuckles. The line is then ready for the trolley wire.

Erection of Trolley Wire.—The most convenient method of erecting trolley wire is as follows:—

A reel of trolley wire, preferably of sufficient length to cover two or more sections, is placed on the reel wagon before described. In addition to the driver two men will be required to attend to the brakes on the reel of wire, and if there is much traffic on the street a third man may be needed to attend the brakes on the reel wagon. The trolley wire is then passed over the top of the tower wagon and made fast to one of the anchorages if it is desired to start from the terminus of a route, otherwise a temporary anchorage is placed at the point of starting. If there are two rows of poles, the anchor is preferably of a V shape; if but a single row, the trolley wire is fastened to the end of a bracket arm to prevent its slipping away from the proper position, and the anchorage run to the next pole. Where temporary anchorages are used it is usually advisable to run a guy from the top of the anchor pole to the next pole, and to this it should be secured as low down as can be done without interfering with the traffic.

The men required in connection with the tower wagon are: one foreman, one linesman and one helper on the platform, one driver, two linesmen, and five or six labourers.

The P.O. vices, block and tackle, "come-along" clamps, pliers, spanners, two ladders, &c., will be the tools required. A sufficiency of 7/14 steel cable will be required, and also a number of stout wire **S** hooks of No. 4 wire gauge.

The reel wagon is now started slowly, and a moderate tension kept on the trolley wire as it is paid out. The tower wagon maintains its position 150 to 200 feet behind the reel wagon, and as it comes directly under the bracket or span wire the trolley wire is raised and hooked to the span with one of the **S** hooks above-mentioned. About every quarter of a mile, or at a greater or less distance according to the traffic, a temporary anchorage is made. A "come-along" clamp is placed on the trolley wire, and an anchorage run out to the next pole ahead, and the trolley wire pulled up approximately into position, and the reeling-out process then proceeds. It is advisable to send a linesman ahead with ladders, to prepare the anchorages at the proper points, so that the tower and reel wagons need not be delayed. Upon reaching a curve of sharp radius it is always best to anchor. The trolley wire is then carried around the curve, preferably with three or four mechanical ears, which are pulled off to convenient poles drawing the trolley wire into its approximate position. Care must be taken to leave slack enough in the trolley wire, as it is easy to work the slack through as the soldering-in proceeds, but hard to work it back. At the far side of the curve another anchorage is put on, to pull against and prevent the stress of a long section of trolley wire from coming on the curve.

The stringing out now proceeds in a similar manner until all the trolley wire is run out, when a final anchorage is put in to hold it in position. Unless there are some special traffic difficulties to deal with, or an exceptional number of curves to anchor, a mile of trolley wire should be run out in two or three hours. If two trolley wires are to be used it is preferable to go back to the beginning and run out a second wire before soldering in. In fact, in many instances 4 miles of trolley wire may be run out in a day and temporarily anchored up. This enables the reel wagon and its crew to be used to the greatest efficiency. In the first pulling up, above described, the wire should be fairly tight, as otherwise, when the final pulling up comes, too much slack is carried forward, and the trolley wire drops down and interferes with the traffic. The final pull-up before soldering-in may be done in lengths of as much as ½ mile if the line is moderately straight, but it is impossible to pull around a sharp curve.

Tension on Trolley Wire.—The exact degree of tension to be put on the wire will depend to a great extent on the temperature at the time the work is carried out. The deflections allowable at different temperatures, and for various lengths of span, are shown in Table D. The stresses resulting from these deflections may be determined from Table C. If the supports were absolutely rigid the deflections in Table D would have to be largely increased for the lower temperatures. In practice the curves of the line allow the stress caused by the shortening of wire, due to a decrease in temperature, to be taken up by the bending of the poles. On lines with many curves the deflections shown in Table D might be decreased some-

TABLE C

STRESSES AT CENTRES OF SPANS RESULTING FROM A GIVEN DEFLECTION

(John A. Roebling's Sons Company.)

Spans in Feet.	Deflections in Decimal Parts of Spans.										
	.001	.002	.003	.004	.005	.006	007	.008	.009	.010	.015
	Multipliers.										
10	1 250.001	625.003	416.671	312.506	250.008	208.343	178.583	156.263	138.903	125.016	83.358
20	2 500.003	1 250.006	833.343	625.013	500.016	416.686	357.166	312.526	277.807	250.033	166.716
30	3 750.005	1 875.01	1 250.015	937.52	750.025	625.03	535.749	468.79	416.711	375.05	250.075
40	5 000.006	2 500.013	1 666.686	1 250.026	1 000.033	833.373	714.332	625.053	555.615	500.066	333.433
50	6 250.008	3 125.016	2 083.358	1 562.533	1 250.041	1 041.716	892.915	781.316	694.519	625.083	416.791
60	7 500.01	3 750.02	2 500.03	1 875.04	1 500.05	1 250.06	1 071.498	937.58	833.423	750.1	500.15
70	8 750.011	4 375.023	2 916.701	2 187.546	1 750.058	1 458.403	1 250.081	1 093.843	972.327	875.116	583.508
80	10 000.013	5 000.026	3 333.373	2 500.053	2 000.066	1 666.746	1 428.664	1 250.106	1 111.231	1 000.133	666.866
90	11 250.015	5 625.03	3 750.045	2 812.56	2 250.075	1 875.09	1 607.247	1 406.37	1 250.135	1 125.15	750.225
100	12 500.016	6 250.033	4 166.716	3 125.066	2 500.083	2 083.433	1 785.83	1 562.633	1 389.038	1 250.166	833.583
110	13 750 018	6 875.036	4 583.388	3 437.573	2 750.091	2 291.776	1 964.414	1 718.896	1 527.942	1 375.183	916.941
120	15 000.02	7 500.04	5 000.06	3 750.08	3 000.1	2 500.12	2 142.997	1 875.16	1 666.846	1 500.2	1 000.3
130	16 250.021	8 125.043	5 416.731	4 062.586	3 250.108	2 708.463	2 321.58	2 031.423	1 805.75	1 625.216	1 083.658
140	17 500.023	8 750.046	5 833.403	4 375.093	3 500.116	2 916.806	2 500.163	2 187.686	1 944.654	1 750.233	1 167.016
150	18 750.025	9 375.05	6 250.075	4 687.6	3 750.125	3 125.15	2 678.746	2 343.95	2 083.558	1 875.25	1 250.375
160	20 000.026	10 000.053	6 666.746	5 000.106	4 000.133	3 333.493	2 857.329	2 500.213	2 222.462	2 000.266	1 333.733
170	21 250.028	10 625.056	7 083.418	5 312.613	4 250.141	3 541.836	3 035.912	2 656.476	2 361.366	2 125.283	1 417.091
180	22 500.03	11 250.06	7 500.09	5 625.12	4 500.15	3 750.18	3 214.495	2 812.74	2 500.269	2 250.3	1 500.45
190	23 750.031	11 875.063	7 916.761	5 937.626	4 750.158	3 958.523	3 393.078	2 969.003	2 639.173	2 375.316	1 583.808
200	25 000.033	12 500.066	8 333.433	6 250.133	5 000.166	4 166.866	3 571.661	3 125.266	2 778.077	2 500.333	1 667.166

RULE.—To find strain in pounds on wire of given span and deflection multiply the numbers column answering to span and deflection by the weight per foot of wire

what with safety, and on very long straight lines a slight increase would be advisable.

TABLE D

(John A. Roebling's Sons Company.)

Temperature in Degrees Fahrenheit at time of erection.	Spans in Feet.					
	75	100	115	130	150	200
	Sag in Inches.					
− 30	1	2	2½	3⅜	4½	8
− 10	1¼	2½	3	3¾	5	9
10	1½	2⅝	3½	4⅛	5¾	10¼
30	1¾	3	4	5⅛	6¾	12
60	2½	4¼	5½	7	9	15⅜
80	3⅛	5⅝	7	8⅝	11¼	18¾
100	4⅓	7	9	11	14	22¼

Hard-drawn copper wire has a tensile strength of from 45,000 to 68,000 lbs. per square inch, according to the degree of hardness—50,000 lbs. may be taken as a fair average for the sizes in most common use.

Annealed copper wire has a tensile strength of from 32,000 to 36,000 lbs. per square inch.

The following table will give the strengths of both hard-drawn and annealed copper wire for the sizes of trolley wire most frequently used:—

B. & S. Gauge.	Diameter, inch.	Strain, lbs.	
		Hard-drawn.	Annealed.
0 000	0.4600	8310	5650
000	0.4096	6580	4480
00	0.3648	5226	3553
0	0.3249	4558	2818

In calculating the maximum stress to which a trolley wire should be subjected, it must be borne in mind that, although the wire is hard-drawn, the soldering-on of the ears anneals it at points. Therefore the maximum stress to which the wire should be subjected at its lowest temperature should leave a margin of safety. It is not usual practice to have this stress exceed about two-thirds of the breaking stress of annealed copper wire. In pulling up before soldering-in it is advisable to use a dynamometer, as otherwise it is extremely difficult to get an even tension on all parts of the line.

Soldering-on Ears.—The trolley being pulled up to the required tension, the next step is to put on the ears and insulators, and the sweating-on is done somewhat as follows:—

The exact position of the ear is marked on the trolley wire. A heavy **U**-shaped cramp (fig. 153) is then clamped to the trolley wire, the **U** standing in a vertical position above the wire. The cramp should be heavy enough to relieve the portion of trolley wire being heated for soldering from practically all stress. The portion of wire to receive the ear should then be well tinned, care being taken not to have the soldering-iron too hot. An acid flux may be used, but it should be thoroughly-well "cut". The ear is now placed in position, the cramp is given a half-turn and brought directly

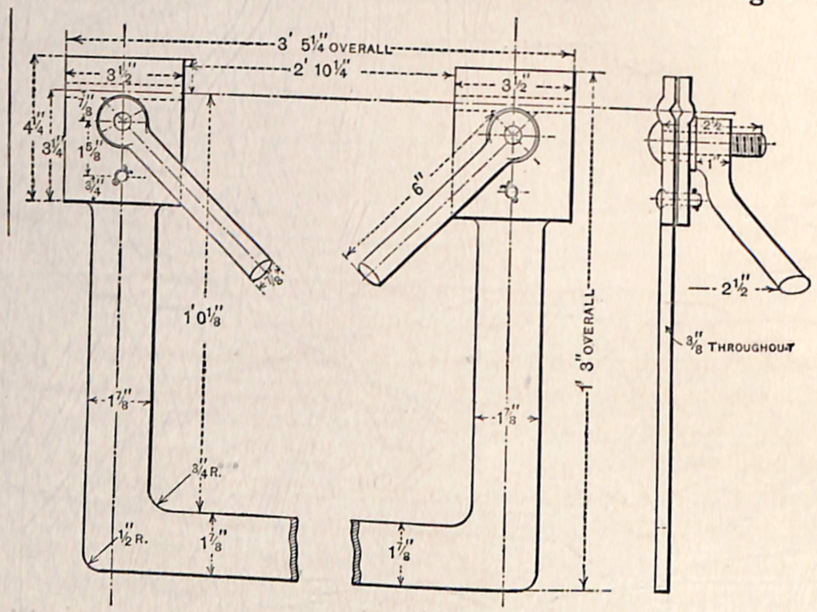


Fig. 153.—Cramp for holding Wires while Ears are being soldered on

underneath the trolley wire, and the ear held in position by gas pliers. The lips of the ear are then carefully hammered down on to the trolley wire so as to force the wire solidly into the groove. The wire and ear are then heated with a soldering-iron, and the solder run in so as to completely fill the groove in the ear. All the acid should be washed off. The wings of the ear should then be dressed down with a file and any surplus solder removed. It is of the greatest importance to get a perfectly smooth surface for the trolley wheel to travel on. The lips should also be dressed down fine at the ends, so that the trolley wheel may have an easy entrance. Considerable care should be used in handling the trolley wire, both in the putting on of the cramp and in the dressing down, not to scratch the surface, as in hard-drawn wire the strength given by the drawing is largely in the surface, and a comparatively shallow scratch seriously weakens the wire. This also applies to the "come-along" cramps, and under no circumstances should a P.O. vice or a draw-tongs be put directly on the wire.

The ear being now finished, the cramp may be removed, and the ear

should stand vertically on top of the trolley wire. The insulating bolt is now slipped through the hanger and screwed into the ear, and the cap of the hanger screwed into place. The exposed portion of steel of the insulating bolt should be painted with P. & B. paint, in fact, sometimes the whole insulating bolt is dipped in P. & B., and while wet slipped into the hanger and screwed up. If mechanical ears are used the cramp is not required, they being simply fastened into position and the insulating bolt put in. They are very much easier and less expensive to erect, and do not weaken the wire by annealing it at each ear, but with circular trolley wire they cannot be arranged to run without sparking, and in time give trouble, the copper crystallizing and breaking off by reason of vibration at the ends of the ear.

Section insulators are put in in much the same manner, except that it is necessary to use a wire-stretching device (fig. 151) in most cases, as the length of the break does not give a sufficient amount of trolley wire to turn up through the insulator and go under the clamp. It is usually necessary to get 2 or 3 inches more trolley wire at these points. Some engineers prefer to put the section insulators in before soldering-in the ordinary work between, and the practice has much to recommend it where the line is fairly straight. It is somewhat more expensive, owing to the extra amount of shifting of the gang and tower wagon required.

The men necessary for soldering-in are a driver, foreman, two linesmen, one man to attend the fire-devil and soldering-irons, and one or two labourers. A melting-pot may be used in place of the soldering-irons, the melted solder being poured over the wire or ear with a ladle until it has heated it to the required degree. This method has points of advantage. It is easier to judge of the temperature of the solder, so there is less danger of overheating the trolley wire, and the results tend to be neater. A gang of men as above described should solder-in about a mile of straight single track per day, and should put up about 3 miles of line with mechanical ears.

Curves and junctions add greatly to the difficulty of the work. In laying out a curve it is advisable to finish the line on one side up to the curve, and place the mechanical ears referred to in as nearly as possible their correct position. The lengths of the pull-off wires are then adjusted, and the curve pulled from the other end to the approximate tension. The positions of the ears having been thus determined, the curve should be slacked off and the permanent ears sweated on, the insulators, hangers, and pull-offs put in place, and the curve again pulled up and adjusted to its final position. Care must be exercised that the stress on any pull-off is not greater than the insulating bolt can bear without bending, and that the pull-off wire does not make too sharp an angle with the trolley wire, in which latter case there would not be clearance for the trolley wheel between the wire and some part of the hanger.

Where the pull-off wires from a curve cross the trolley wire on the main line it is necessary to use an insulator that will prevent their coming in contact from the swaying of the line. The insulator shown in fig. 121 is more suitable for this than the ordinary type of straight-line or curve

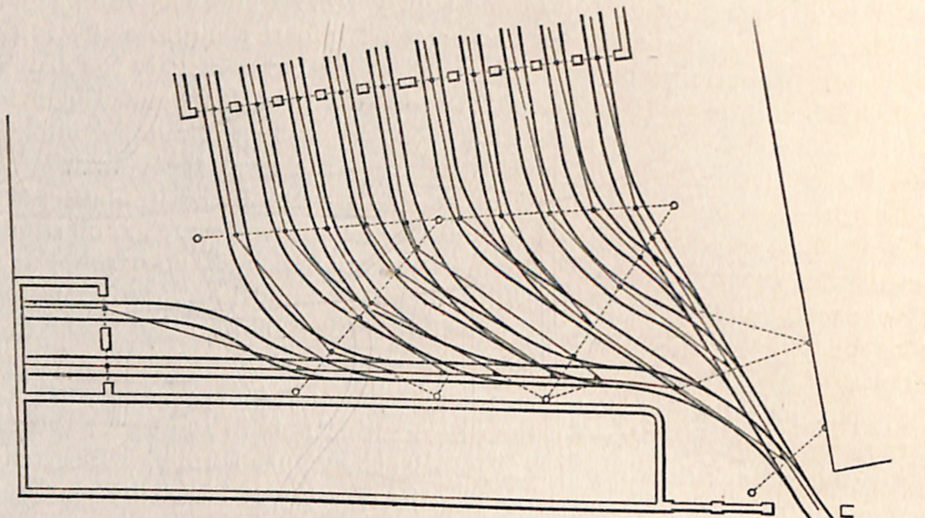


Fig. 154.—Car Barn Layout. Location of Poles and Pull-offs.

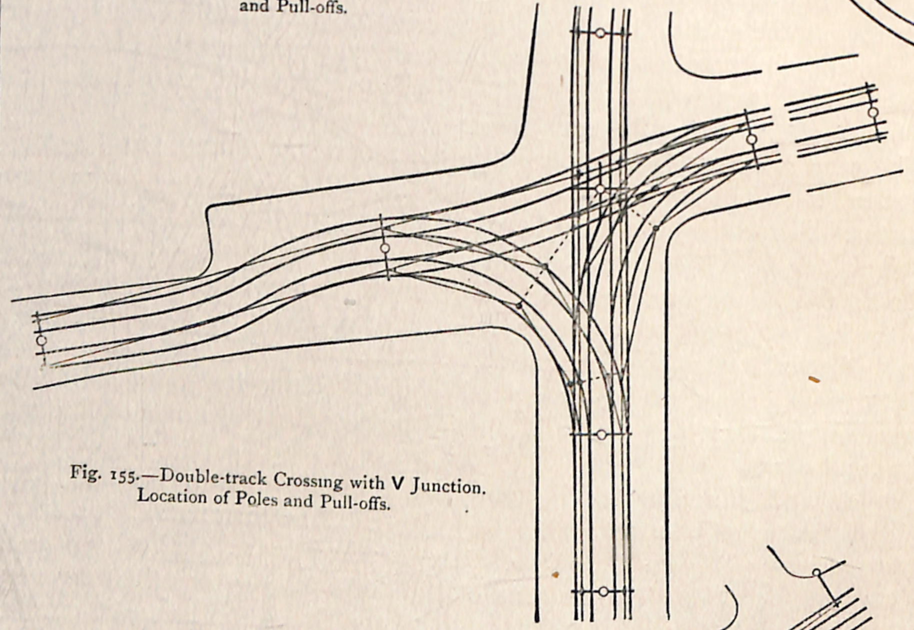


Fig. 155.—Double-track Crossing with V Junction. Location of Poles and Pull-offs.

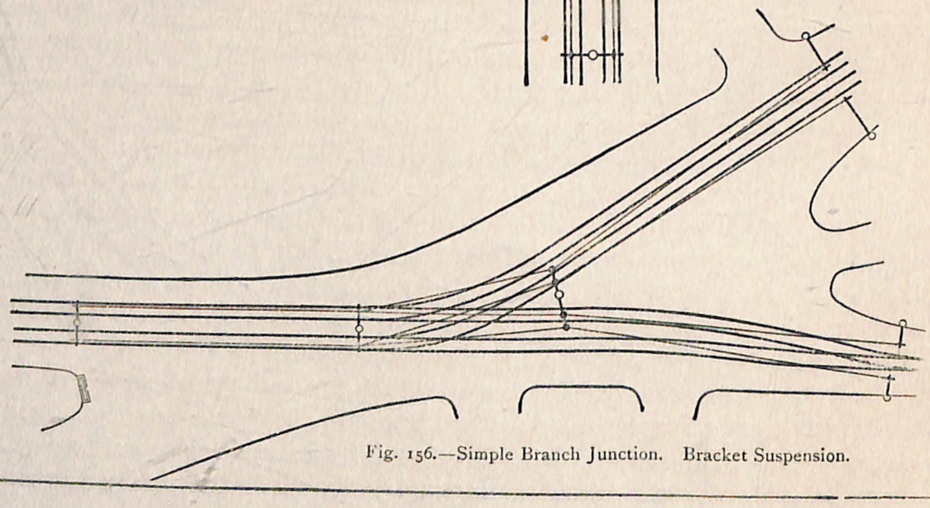


Fig. 156.—Simple Branch Junction. Bracket Suspension.

hanger, as it is much lighter. In laying up a Y curve the stresses can often be made to balance each other. In some cases where a number of pull-offs run to one pole it is better to run them into a bull-ring at a convenient point, and from the bull-ring run a single heavy cable to the pole. Several typical curves and junctions are shown (figs. 154, 155, and 156), with the usual methods of pulling into position.

Frogs.—In setting frogs for the centre-running trolley it is necessary to locate them with considerable exactness. The diagram, fig. 157, shows the principle by which these frogs are made to work. The frog is set at D, slightly out of centre as to the straight-through track in the direction of the branch line. This gives a tendency for the trolley wheel to drag against the side of the frog and follow the straight line. The frog must

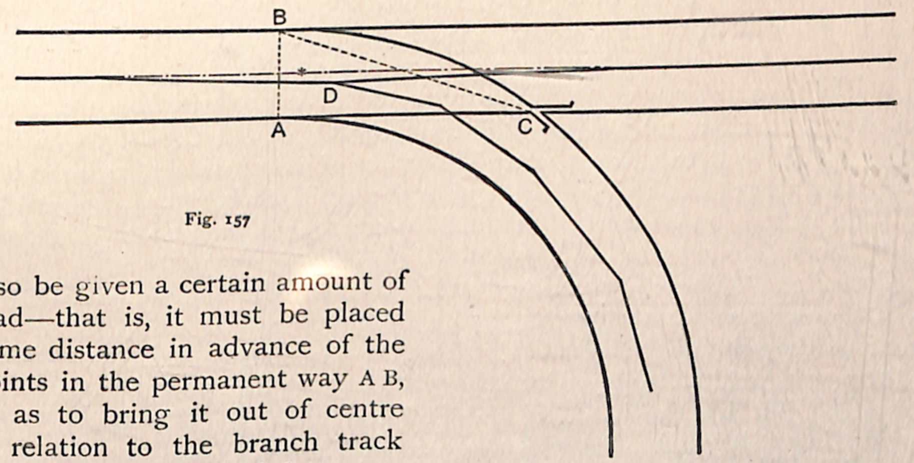


Fig. 157

also be given a certain amount of lead—that is, it must be placed some distance in advance of the points in the permanent way A B, so as to bring it out of centre in relation to the branch track towards the outside of the curve, or in the centre of the triangle A B C. The exact amount of the lead will be determined by the radius of the curve, the height of the trolley wire from the rail, height of car, and length of trolley arm, and also the superelevation of the outside rail of the curve. If both rails are perfectly level the position of the frog would be approximately as shown; but the frog should not be secured in place until it has been tried, and a portion of the trolley wire on the branch line is often run through the frog and coiled up so as to enable the lead to be reduced if desired.

Frogs are usually provided with eyes for the attachment of guy wires by which they can be pulled into their exact positions. The superelevation of the rail is a feature that is often overlooked. In the setting of a frog, where the outer rail has a 1-inch superelevation, the line being 21 feet in height and the gauge standard, the frog must be 4 or 5 inches farther towards the inside of the curve.

Frogs that are to be set for the swivel-headed trolley are set very much on the same principle, but more latitude as to the exact position is allowable. There is no necessity for any lead on the straight-through track, but if it is intended to work with a fixed frog a much stronger lead will be required for the branch line.

If a mechanically-worked frog is used the trolley wheel will take it in almost any position in which it can be reached; but it is not advisable to strain the following capabilities of the swivelling trolley to their utmost, and it is therefore wise to follow the general rule as far as circumstances will permit, and the principle will apply even though the frog is set at a considerable distance away from the centre line of the track.

There are two methods of attaching the frog to the trolley wire (fig. 131)—one by soldering, in a similar manner to the attachment of an ear; the other by passing the trolley wire under a suitably-designed clamp with curved jaws, the curves being so designed that the pressure of the trolley wheel does not bend the trolley wire over a sharp angle and thus cause it to break off. The second type is distinctly preferable, as it is more easily erected, and its position more easily adjusted after erection. This last is a great convenience, for, owing to the stretching of wires or slight movement of some of the poles, it may be necessary to adjust the position of the frog after the line has been in operation for some time.

It is always necessary to run the frogs and crossings with some caution, as, owing to their extra weight, they form rigid spots in the line, which, if run at speed, tend to throw the trolley wheel downwards and clear of the wire. In this respect frogs which guide the trolley wheel by a groove as well as a flange can be worked at much higher speed than those that trust to the flanges alone.

Crossings.—These are attached to the trolley wires in a similar manner to that described for the frogs. In laying out the pull-offs around the junctions they should be so arranged that the crossing comes between two of them, and neither trolley wire changes its direction at the crossing. It is best to put up the junction and pull it into its final position before putting in the crossing. An adjustable crossing may then be put in in the case of centre-running trolley, and in the case of the swivel trolley the crossing may be cast to the exact angle; or it may be possible, by a slight adjustment of the pull-offs, to bring the trolley wires to one of the standard angles for which these crossings are usually stocked. Or the semi-adjustable crossing already described may be used. There are a large number of insulated crossings available should it be desirable to insulate one trolley wire from the other, but these should be avoided whenever it is possible, as they are apt to give trouble in practice. There is very little necessity for their use.

Feeding-in wires from the switch-boxes to the trolley wire are usually made up of fine strands of copper, to be as flexible as possible. They are preferably insulated with rubber, and may be lead-covered, wire-armoured, or, with advantage, sheathed in silicate rubber. They should have a sectional area equal to the trolley wires they feed, but this is not absolutely essential.

There are several methods employed in running the feeding-in wires from the pole to the trolley wire. In some cases a small cross-arm of the same length as the distance between the binding-posts on the section insulator is attached to the pole, and provided with insulators at each end. The wires are then run straight from these insulators to the binding-posts on the feed-cars or section insulators, and if the trolley is not far distant

from the pole no intermediate supports are necessary, and the appearance is neat. Another method (fig. 158), which is perhaps more generally used, is to bring the feeding-in wires through the pole at a slightly higher level than the bracket or span wire, and bind them closely in to the pole and the bracket arm or span wire, until the feed-ear or section insulator is reached, when the wires branch out to their respective terminals. The feeding-in wires should always be provided with a bushing where they enter and leave the pole, and the ends should be carefully sealed to prevent moisture from getting into the cable. The arrangements for switches and feeding-in wires will depend largely on the method adopted for dividing the trolley wire into sections. The ideal arrangement of these sections is to have each fed normally from one point, but capable of being fed from two or more points, which, if possible, should be connected to different feeders.

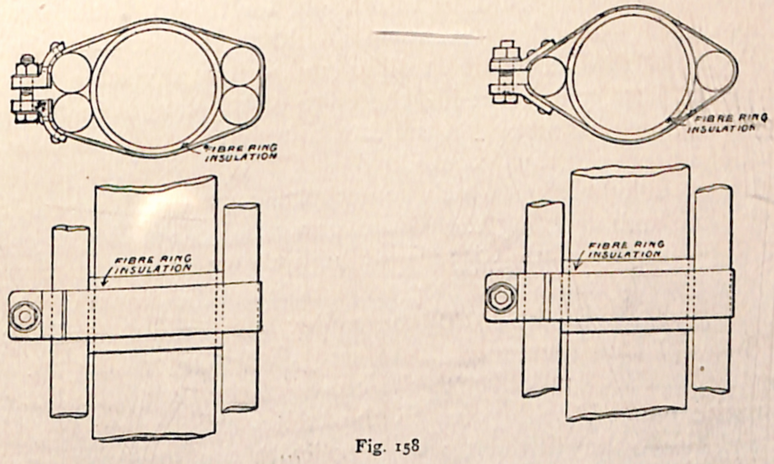


Fig. 158

Car Barns, Bridges, &c.—In car barns and under bridges where there is a metallic structure or the head-room is small, it is usual to erect an inverted wooden troughing, 11 or 12 inches in width and 3 or 4 inches in depth. This troughing is secured to the roof or bridge girders, and to it are bolted bridge hangers (fig. 112) at intervals of 10 or 12 feet. In the car barn this troughing is wholly unnecessary, and is probably a survival of the earlier practice, when uninsulated trolley poles were in use. It is a source of danger rather than of safety, as it is very easy to place the trolley wheel on the troughing, and against the wire but not on it. In which case the car runs along until clear of the barn, when the trolley flies up and gets entangled with the overhead work, which is usually complex at the car sheds. A better method is to put a span wire across the sheds at each principal, and put in an ordinary straight-line hanger. The span wire should be stayed to the truss-rod of the principal about every 20 or 30 feet. This gives a flexible and easy-running arrangement which is much less in the way than the troughing.

In the case of bridges passing over the line it is somewhat different, as the head-room is often much restricted and it is necessary to run the trolley wire as close as possible to the under side of the bridge. Some device is necessary to prevent the trolley wheel from pressing the wire up against the bridge and causing a short circuit. The usual method of bolting the bridge hangers directly to the troughing is not wholly satisfactory; owing to the expansion of the wire between the rigid points of support it puts a good deal of slack into the short spans generally used.

If the hangers are given a slight amount of play longitudinally, the tension on the trolley wire will be even throughout its length, and this buckling will be avoided. Details of this arrangement are shown (fig. 159), designed to take up the minimum amount of head-room. It will be noticed that the arrangement shown gives a treble insulation at this point. This is not essential from the tramway standpoint, but the electrical advisers of the railway companies, whose approval is generally necessary for the attachment of wires to a bridge, are usually somewhat exacting in their requirements with regard to insulation, for fear of interference with the railway signals. The designs shown should meet all reasonable requirements. Where the swivel-headed trolley is used it is advisable to place the trolley wires at least 3 feet outside the edge of the car, as in this position it is impossible for passengers on the roof to touch them, and several extra inches of head-room are thus secured.

Another form of bridge which sometimes causes difficulty is the old-fashioned stone arch carrying the road over a canal or small stream. These bridges are frequently made with a very high crown and sharp approaches, and, as it is usually impossible to place a pole on the crown of the bridge, they seriously reduce the height of the trolley above the car. They can be dealt with by placing four poles, from 2 to 3 feet longer than the standard pole, as close as they can be set to the crown of the arch. Pull-offs can be run from the top of these poles to the trolley wire at the centre of the bridge, and the trolley lifted up to practically the standard height.

Guard Wires.—Whenever the trolley wire is in proximity to telephone or telegraph wires, the British Board of Trade, and the Governments of the several European countries, require that devices shall be used to prevent a fallen telephone or telegraph wire coming in contact with a trolley wire. To quote the British Board of Trade regulations: "If and whenever telegraph, telephone, or other wires, unprotected with a permanent insulating covering, cross above, or are liable to fall upon, or to be blown on to, the overhead conductors of the tramways, efficient guard wires shall be erected and maintained at all such places".

It was formerly the practice to insulate these guard wires carefully, but the Board of Trade regulations now provide for these guard wires being very carefully bonded to the rails through their supports at each end and at intervals of not more than five spans. It is therefore only necessary to secure the guard wire proper to the span wire by the small clips shown (fig. 160), or to the standards provided on the bracket arms (figs. 161 and 105).

The theory is that the falling wire will first come in contact with the earthed guard wire, and then, if, from any coiling action or from being caught by a passing vehicle, it should come in contact with the trolley wire, an absolute short circuit will be formed which will open the circuit-breakers

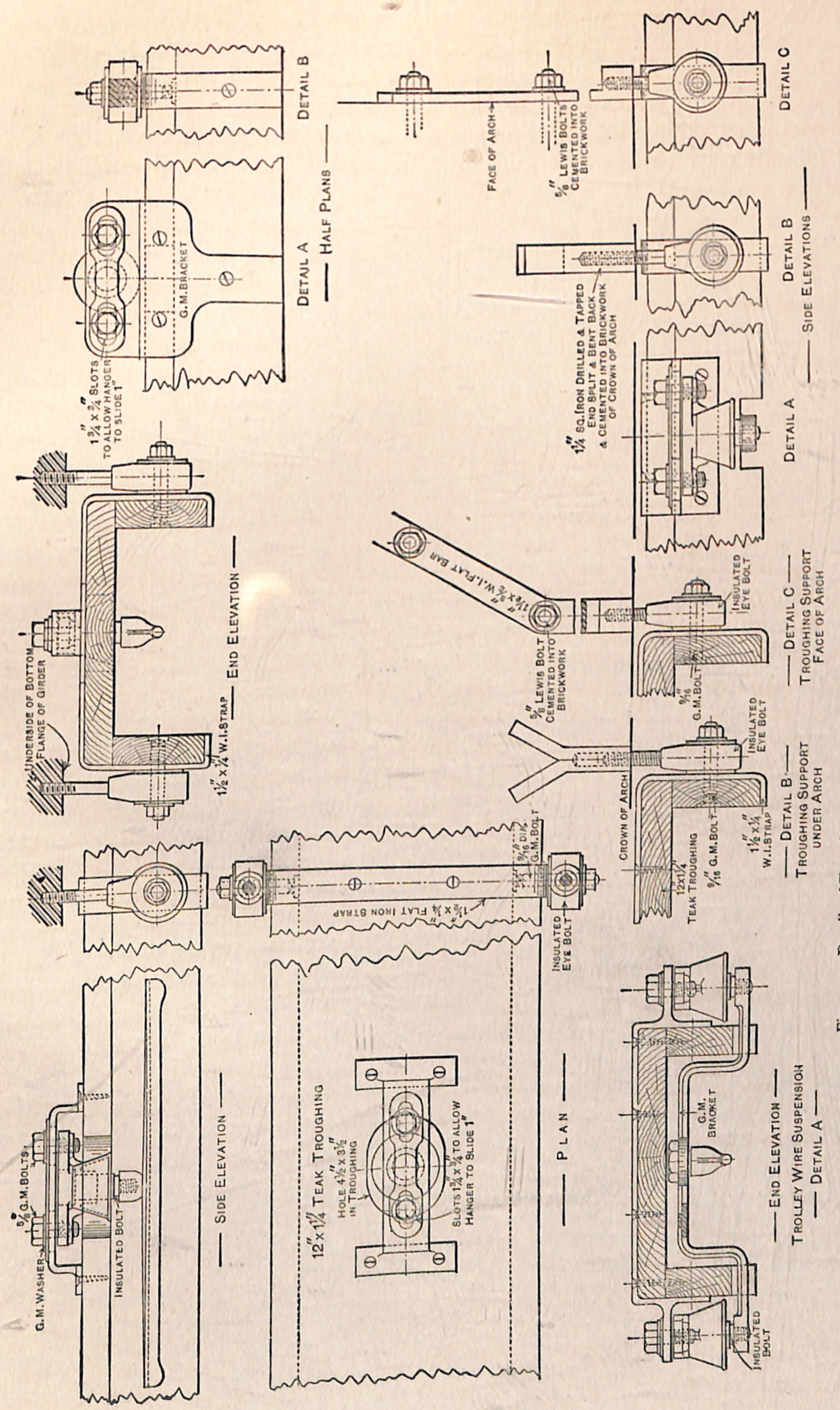


Fig. 159.—Details of Troughing, Insulators, and Hangers under Girder and Brick-Arch Bridges

in the generating station and cut the current off the trolley wire. Seven-stranded steel cable of 16 gauge is more satisfactory for the purpose of guard wires than the equivalent single wire of No. 8 S.W.G.

Where guard wires are used, their additional weight and consequent stress must be taken into consideration in determining the size and location of poles. Where wires cross curves or junctions it is practically impossible to erect efficient protective devices, and arrangement should be made with the owners of these wires to deflect them at such points.

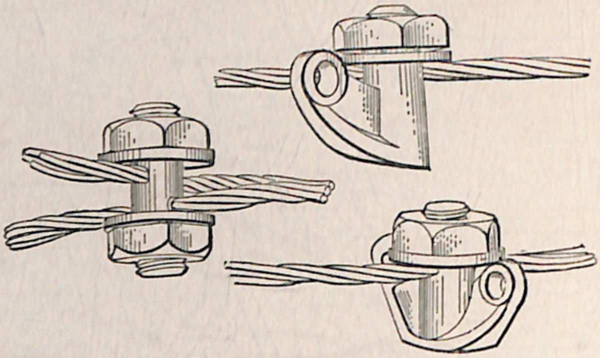


Fig. 160.—Guard-wire Clips

The attitude of the authorities towards tramways on the guard-wire question is somewhat unfair. They compel the tramway to afford protection against defective workmanship or maintenance on the part of the owners of the telephone or other telegraph wires, not only in regard to wires in position before the tramways were built, but any additional wires that may be erected. Guard wires are very unsightly, a considerable expense, and a source of danger to the tramway, as, in event of the trolley leaving the wire, it is very liable to get caught in the guard wires and pull them down. The actual amount of protection afforded is in most instances very slight. This refers particularly to long spans, and spans crossing the trolley lines at a sharp angle. Co-operation between the respective owners of the wires would enable a much more efficient protection to be given, with much less disfigurement. But this co-operation is difficult to arrive at, as the owners of the wires usually adopt an impossible attitude, saying, in effect: The Board of Trade regulations throw the whole responsibility on you; why should we trouble ourselves in the matter?

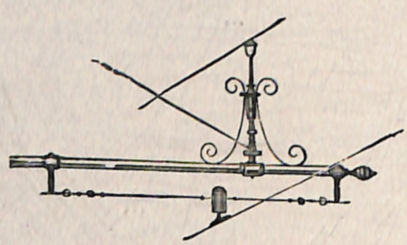


Fig. 161.—Guard-wire Standard

Full details as to the statutory requirements of the British Board of Trade and British Post Office will be obtained from the Regulations and Explanatory Memoranda issued by these authorities. Care should be taken to have the latest issued regulations, as those of an earlier date are generally superseded by newer publications.